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1899-1900

SOME FEATURES OF THE DRIFT ON STATEN ISLAND, N. Y.

ARTHUR HOLLICK.

(Read October 17, 1898.)

[Plate I.]

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INTRODUCTION.

GENERAL GEOLOGICAL CONDITIONS.

IN order that the full significance of many of the features of the drift on Staten Island may be appreciated it is necessary to have at least a fair idea of the general geological conditions which prevail there. Topographically the island may be roughly divided into a hill region at the north and east and a plain region at the south and west. The hill region is limited on the east and south by a ridge of serpentine, which extends from the point nearest to New York City, at New Brighton, to about the center of the island, at Richmond. The eastern and southern border of this ridge is abrupt, in places forming a steep escarpment and reaching a maximum elevation of 380 feet, at a point distant about a mile from the border. From the summit of the ridge to the north and west the surface is an irregular slope to tide water at the shores of the kills, which separate the island from the adjoining mainland. A low trap ridge is the only other well-defined rock exposure in this region. The plain region comprises the remainder of the island. It is an isolated portion of the Atlantic coastal plain, over the greater part of which is spread a series of morainal hills with a maximum elevation of 175 feet. The underlying strata are Cretaceous. Almost the entire area of the island is covered by boulders, till or modified drift.

TERMINAL MORAINE.

Earlier Descriptions.

Probably the earliest published account of the drift on Staten Island is in a communication from Mr. James Pierce, to the editor of the *American Journal of Science*, in 1818. In this he says: "Large beds of water-worn siliceous pebbles, in no way differing from those washed by the ocean, are seen on the height of the ridge, in which excavations have been made several feet, leaving the depth of the mass uncertain. * * * Adjacent to Fort Tompkins, detached pieces of copper ore have been found. I have observed petrifactions of marine shells in rocks excavated in that neighborhood, twenty feet from the surface and sixty above the ocean."

In 1838 Mr. W. W. Mather's preliminary report on the geology of New York was issued, in which he mentions the occurrence of fossiliferous boulders on Staten Island, as follows: "A boulder of limestone filled with fossil shells, and similar to that of Becroft's Mountain, near Hudson, was dug from a well at a considerable depth. A boulder of siliceous limestone, like one of the strata of the Helderberg, containing fossils, was dug from another well on Staten Island. * * * I found a small boulder of decomposed rock, on the shore near the southwest lighthouse, filled with fossil remains similar to those of the middle limestone of Becroft's Mountain, Columbia county."

In his final report in 1843, he frequently refers to features of the drift on the island, noting among other facts that the soil is largely colored red by reason of the quantity of red sandstone contained in it.

In 1881 Dr. N. L. Britton read two papers on the geology of the island, before the Academy, in which the general features of the drift were discussed and the terminal moraine was described and mapped. (Annals, ii, 161–182; pls. xv, xvi. Transactions, i, 56, 57.)

During the same year the Natural Science Association of Staten Island was organized, thus providing a medium for the recording of local notes and the preservation of local specimens, and it is largely upon these notes, scattered through its Proceedings, and the specimens contained in its museum, that the present paper is based.

Location and Extent.

The terminal moraine extends through the island in an irregular line, from Fort Wadsworth, at the Narrows, to Tottenville, opposite Perth Amboy, N. J. It reaches tide-water at these localities and also near Great Kills, between which point and Prince's Bay it formerly extended beyond what is now the shore line. Only two limited areas are driftless. One of these, about 7½ square miles in area, is in the sinus where the moraine bends northward and rests upon the serpentine ridge, in the vicinity of New Dorp; the other is a similar, smaller area, in the vicinity of Tottenville.

Structure.

Where the moraine rests upon the serpentine ridge it presents but few features that are especially striking, consisting entirely of boulder till, gravel and occasional deposits of clay, varying in depth from a mere layer of scattered boulders to accumulations eighty feet in thickness.

Throughout the plain region, however, it is invariably found to consist of a core of contorted Cretaceous clays and Tertiary gravels, on top of which is the true morainal material. This structure is the same throughout Long Island, Block Island and Martha's Vineyard and is manifestly the result of ice action, first squeezing upward and pushing forward the incoherent strata of the coastal plain, afterwards melting and depositing the glacial débris on the ridge thus formed.

CHARACTER OF THE MATERIAL.

The morainal constituents comprise practically all rocks which outcrop between Staten Island and the Adirondacks. The boulders most abundantly represented are of diabase, evidently derived from the Newark system of New Jersey, while the bulk of the finer material which enters into the composition of the till is Triassic shale or sandstone, giving to it a prevailing red color. A large number of other boulders have been more or less definitely identified from their lithological characters, but by far the most satisfactory determinations have been made from those in which fossils were found.

LISTS OF FOSSILS.

Two lists of these fossils have been prepared. The first contains 112 Palæozoic species, the second 42 Mesozoic species.

I. PALÆOZOIC FOSSILS FOUND IN THE DRIFT ON STATEN ISLAND.

	NAME.	GEOLOGICAL HORIZON.	LOCALITY.
1.	Ambonychia radiata Hall.	Hudson (Lorraine)	Kreischerville.
2.	Anoplia nucleata (Hall).	Oriskany.	Clifton.
3.	Anoplotheca concava (Hall).	Lower Helderberg.	Clifton.
4.	" flabellites (Hall).	Oriskany.	Clifton. Tottenville.
5.	Aspidocrinus scutelliformis Hall.	Lower Helderberg.	Prince's Bay.
6.	Atrypa reticularis Linn.	Schoharie. Lower Helderberg.	Prince's Bay. New Brighton.
7.	" " impressa Hall.	Schoharie.	New Brighton.
8.	Atrypina imbricata Hall.	Lower Helderberg.	Clifton.
9.	Aviculopecten recticostus Hall.	Oriskany.	Clifton.
10.	" umbonatus Hall.	Lower Helderberg.	Prince's Bay.

I. Palæozoic Fossils found in the Drift on Staten Island.

(*Continued.*)

	NAME.	GEOLOGICAL HORIZON.	LOCALITY.
11.	Chonophyllum conatum Hall.	Schoharie.	New Brighton.
12.	Chonostrophia complanata Hall.	Oriskany.	Clifton.
13.	Conocardium attenuatum Conr.	Schoharie.	New Brighton.
14.	Cryptopora mirabilis Nicholson.	Schoharie.	New Brighton.
15.	Cyathophyllum rugosum Ed. & H.	Schoharie.	New Brighton.
16.	Cyrtina rostrata Hall.	Oriskany.	Prince's Bay.
17.	Cyrtolites (?) curvilineatus Conr.	Schoharie.	New Brighton.
18.	Cyrtoceras eugenium Hall.	Schoharie.	New Brighton.
19.	Cystiphyllum sp.?	Schoharie.	Prince's Bay.
20.	Dalmanella sub-carinata Hall.	Lower Helderberg.	Clifton.
21.	“ concinna Hall.	Lower Helderberg	Clifton.
22.	“ testudinaria (Dalm.).	Hudson (Lorraine)	Tottenville. Richmond Valley. Prince's Bay. Rossville. New Brighton.
23.	Dalmanites anchiops Green.	Schoharie.	New Brighton.
24.	Dalmanites micrurus Green.	Lower Helderberg.	Clifton.
25.	“ nasutus Conr.	Lower Helderberg.	New Brighton.
26.	“ pleuroptyx Green.	Lower Helderberg.	Clifton.
27.	Dictyonema fenestratum Hall.	Upper Helderberg.	Clifton.
28.	Eatonia medialis Vanux.	Lower Helderberg.	Clifton.
29.	“ peculiaris Conr.	Oriskany.	Clifton. Prince's Bay.
30.	Favosites emmonsii Rom.	Schoharie.	New Brighton.
31.	Fenestella æsyle Hall. (?)	Lower Helderberg.	Prince's Bay.
32.	“ biserialis Hall.	Lower Helderberg.	Clifton.
33.	“ nervia Hall.	Lower Helderberg.	Clifton. New Brighton.
34.	“ obliqua Hall.	Lower Helderberg.	Clifton.
35.	“ parallela Hall.	Schoharie.	Prince's Bay.
36.	“ precursor Hall.	Lower Helderberg.	New Brighton.
37.	Fistulipora sp.?	Lower Helderberg.	Tottenville.
38.	Gosseletia mytilimera Conr.	Lower Helderberg.	Clifton.
39.	Heliophyllum exiguum Billings.	Schoharie.	New Brighton.
40.	Hipparionyx proximus Vanux.	Oriskany.	Clifton.
41.	Leptæna rhomboidalis Wahl.	Schoharie. Lower Helderberg.	Prince's Bay. New Brighton. Clifton.
42.	Leptænisca concava Hall.	Lower Helderberg.	Prince's Bay.
43.	Lichas bigsbyi Hall (?)	Lower Helderberg.	Prince's Bay.
44.	“ pustulosus Hall.	Lower Helderberg.	Prince's Bay.
45.	Lichenalia concentrica Hall.	Schoharie.	New Brighton.
46.	“ sp.?	Lower Helderberg.	Prince's Bay.
47.	Lingula rectilatera Hall.	Lower Helderberg.	Huguenot.
48.	Megambonia sp.?	Oriskany.	Tottenville.
49.	Meristella arcuata Hall.	Lower Helderberg.	Clifton. New Brighton.
50.	“ bella Hall.	Lower Helderberg.	Prince's Bay.

I. PALÆOZOIC FOSSILS FOUND IN THE DRIFT ON STATEN ISLAND.

(*Continued.*)

	NAME.	GEOLOGICAL HORIZON.	LOCALITY.
51.	Meristella lata Hall.	Oriskany.	Prince's Bay.
52.	" nasuta Conr.	Schoharie.	Prince's Bay.
53.	Metaplasia pyxidata Hall.	Oriskany.	Clifton.
54.	Nucleospira concinna Hall.	Schoharie.	Prince's Bay.
55.	Orthoceras pelops Hall.	Schoharie.	New Brighton.
56.	Orthodesma parallelum Hall.	Hudson (Lorraine).	Kreischerville.
57.	Orthothetes woolworthanus Hall.	Lower Helderberg.	Clifton.
58.	Pentamerella arata Conr.	Schoharie.	New Brighton.
59.	Phacops cristatus Hall.	Schoharie.	Prince's Bay.
60.	" logani Hall.	Lower Helderberg.	Clifton.
61.	Phillipsastrea verneuilii Ed. & H.	Schoharie.	New Brighton.
62.	Pholidops arenaria Hall.	Oriskany.	Clifton. Tottenville.
63.	Platyceras nodosum Conr.	Oriskany.	Clifton. Prince's Bay.
64.	Platyostoma ventricosum Hall.	Oriskany.	Clifton.
65.	Plectambonites sericeus (Sow.).	Hudson (Lorraine).	Clifton. Rossville.
66.	Proëtus crassimarginatus Hall.	Schoharie.	New Brighton.
67.	Pterinea communis Hall.	Lower Helderberg.	Prince's Bay.
68.	" gebhardi Hall.	Oriskany.	Prince's Bay. Clifton.
69.	" textilis Hall.	Oriskany.	Clifton. Tottenville.
70.	Pterinopecten bellulus Hall.	Lower Helderberg.	Prince's Bay.
71.	Ptilodyctia tenuis Hall.	Lower Helderberg.	Clifton.
72.	Rafinesquina alternata Emmons.	Hudson (Lorraine).	Prince's Bay.
73.	Rensselæria mutabilis Hall.	Lower Helderberg.	Prince's Bay.
74.	" ovoides Eaton.	Oriskany.	Prince's Bay. Clifton.
75.	Rhipidomella alsa Hall.	Schoharie.	Prince's Bay. New Brighton.
76.	" eminens Hall.	Lower Helderberg.	Prince's Bay.
77.	" oblata Hall.	Lower Helderberg.	Prince's Bay New Brighton.
78.	" peloris Hall.	Schoharie.	New Brighton.
79.	Rhychonella multistriata Hall.	Oriskany.	New Brighton.
80.	" sp.?	Schoharie.	New Brighton.
81.	" sp.?	Lower Helderberg.	New Brighton.
82.	Schizophoria multistriata Vanux.	Lower Helderberg.	Clifton.
83.	Scolithus linearis Hall.	Potsdam.	Tottenville. Prince's Bay. Clifton.
84.	Spirifer arenosus Conr.	Oriskany.	Tottenville. New Dorp.
85.	" arrectus Hall.	Oriskany.	Tottenville. Prince's Bay. New Dorp. Clifton. Old Place.

I. PALÆOZOIC FOSSILS FOUND IN THE DRIFT ON STATEN ISLAND.

(Continued).

	NAME.	GEOLOGICAL HORIZON.	LOCALITY.
86.	Spirifer concinnus Hall.	Lower Helderberg.	Prince's Bay.
87.	" cyclopterus Hall.	Lower Helderberg.	Prince's Bay. New Brighton.
88.	" macropleurus Conr.	Lower Helderberg.	New Brighton. Clifton.
89.	" mucronatus Conr.	Hamilton.	New Brighton. Richmond.
90.	" perlamellosus Hall.	Lower Helderberg.	New Brighton Clifton.
91.	Streptelasma strictum Hall.	Lower Helderberg.	New Brighton.
92.	Stropheodonta beckii Hall.	Lower Helderberg.	Prince's Bay. Huguenot. Clifton.
93.	" demissa Conr.	Schoharie.	New Brighton.
94.	" inæquiradiata Hall.	Schoharie.	Prince's Bay. New Brighton.
95.	" magnifica Hall.	Oriskany.	Tottenville. Clifton.
96.	" parva Hall.	Schoharie.	New Brighton.
97.	" perplana Conr.	Schoharie.	New Brighton.
98.	" varistriata Conr. (?)	Lower Helderberg.	Prince's Bay.
99.	" " arata Hall.	Lower Helderberg.	Prince's Bay.
100.	Strophonella ampla Hall.	Schoharie.	New Brighton.
101.	" headleyana Conr.	Lower Helderberg.	Huguenot.
102.	" punctulifera (Conr.)	Lower Helderberg	Tottenville.
103.	" radiata (Vanux.)	Lower Helderberg.	Clifton.
104.	" sp.?	Lower Helderberg.	New Brighton.
105.	Syringopora hisingeri Billings.	Schoharie.	New Brighton.
106.	Taonurus cauda galli (Vanux.)	Schoharie.	Tottenville. Clifton.
107.	Tentaculites gyracanthus (Eaton.)	Lower Helderberg.	Tottenville.
108.	Trematopora corticosa Hall.	Lower Helderberg.	New Brighton.
109.	" regularis Hall.	Lower Helderberg.	New Brighton.
110.	" rhombifera Hall	Lower Helderberg.	Clifton.
111.	Trematospira concava Hall.	Lower Helderberg.	New Brighton.
112.	Uncinulus nobilis Hall.	Lower Helderberg.	Clifton.

NOTE.—The identifications in this list were all either made or verified by Professor R. P. Whitfield and Mr. L. P. Gratacap, of the American Museum of Natural History. For the final revision I am indebted to Mr. Gilbert van Ingen of Columbia University.

II. MESOZOIC FOSSILS FOUND IN THE DRIFT ON STATEN ISLAND.

	NAME.	GEOLOGICAL HORIZON.	LOCALITY.
1.	Equisetum rogersi Schimp (?)	Triassic.	Clifton.
2.	Andromeda parlatorii Heer.	Cretaceous (Clay Series.)	Tottenville.
3.	Aralia rotundiloba Newb. (?)	" " "	"
4.	Dalbergia hyperborea Heer.	" " "	"
5.	Dammara borealis Heer. (?)	" " "	"
6.	Dewalquea grœnlandica Heer.	" " "	"
7.	Diospyros primæva Heer.	" " "	"
8.	Eucalyptus geinitzi Heer.	" " "	"
9.	Ficus atavina Heer. (?)	" " "	"
10.	" proteoides Knowlton.	" " "	"
11.	" woolsoni Newb. (?)	" " "	"
12.	Hedera sp. ?	" " "	"
13.	Laurus plutonia Heer.	" " "	"
14.	Liriodendron primævum Newb.	" " "	"
15.	Liriodendropsis simplex Newb.	" " "	Tottenville. Prince's Bay.
16.	Magnolia glaucoides Newb.	" " "	Tottenville.
17.	" longifolia Newb. (?)	" " "	"
18.	Moriconia cyclotoxon Deb. and Ett.	" " "	Prince's Bay. Clifton.
19.	Myrica longa Heer.	" " "	Clifton.
20.	Myrsine elongata Newb.	" " "	"
21.	Paliurus sp. ?	" " "	Tottenville.
22.	Pinus sp. ? (cone and cone scales).	" " "	Tottenville. Clifton
23.	Platanus newberryana Heer (?)	" " "	Prince's Bay.
24.	Populus apiculata Newb. (?)	" " "	Clifton.
25.	" harkeriana Lesq.	" " "	Tottenville.
26.	Proteoides daphnogenoides Heer.	" " "	"
27.	Pterospermites modestus Lesq.	" " "	Tottenville.
28.	Rhamnus pfaffiana Heer.	" " "	Tottenville. Prince's Bay.
29.	Salix inæqualis Newb.	" " "	Clifton.
30.	Sapindus morrisoni Lesq.	" " "	Tottenville. Prince's Bay.
31.	Sequoia reichenbachi Gein.	" " "	Tottenville.
32.	Sterculia snowii Lesq. (?)	" " "	"
33.	" sp. ?	" " "	"
34.	Thinnfeldia lesquereuxiana Heer.	" " "	Tottenville. Prince's Bay.
35.	Tricalycites papyraceus Newb.	" " "	Tottenville.
		" (Marl Series).	
36.	Aphrodina tippana Conr. (?)	" " "	Clifton.
37.	Cardium dumosum Conr.	" " "	"
38.	Gryphæa sp. ?	" " "	"
39.	Ostrea plumosa Morton (?)	" " "	"
40.	Pachycardium burlingtonense Whitf.	" " "	Tottenville.
41.	Terebratella vanuxemi Lyell & Forbes.	" " "	"
42.	Terebratulina atlantica Morton (?)	" " "	"

NOTE.—In the preparation of this list I am indebted to Dr. Lester F. Ward of the United States Geological Survey, for verifications of doubtful species of plants and to Professor Whitfield for identification of the molluscs. All the species enumerated in the two lists, together with many others not yet identified, are in the museum of the Natural Science Association of Staten Island.

A number of species first described from Staten Island specimens are not included, for the reason that the geological age of such species might be questioned.

SUMMARY AND CONCLUSIONS.

There are but few rock outcrops on the island sufficiently hard to preserve the glacial striæ, but from the few that are available the direction has been ascertained to be between north 13 degrees west and north 20 degrees west, which, if extended northward, may be seen to cross the known outcrops of the rocks represented in the list.

Satisfactory lithological identifications have also been made of labradorite and other crystalline boulders, which would extend the geographic and geologic range of the morainal material at one extremity into the Archæan of the Adirondack region and of sandstone, conglomerate and gravel which would extend it at the other extremity into the Tertiary of the coastal plain. If the lists alone are examined, however, it may be seen that in the Palæozoic the range of the fossils is from the Potsdam to the Hamilton while in the Mesozoic there is represented the Trias and the middle and upper Cretaceous.

There are, therefore, two breaks—the first between the Hamilton and the Trias, the second between the Trias and the middle Cretaceous. Indications of either Carboniferous or Jurassic rocks are entirely lacking, which is in accordance with our knowledge in regard to the absence of any rocks of these periods along the line of glacial movement towards Staten Island.

Probably one of the most interesting facts which may be noted, from an examination of the list of localities, is that the Cretaceous fossils are confined to those parts of the moraine which lie south of the serpentine ridge. Tottenville and Prince's Bay are the two localities at one extremity of the island where they occur, while Clifton is the one locality at the other. Between these two extremities they are absent, and the natural conclusion to be drawn from this fact is that there was never any Cretaceous extending around to the north of the serpentine ridge, otherwise some evidence or at least indications of it ought to occur in that portion of the moraine which rests upon the ridge, but thus far not a fragment of a fossil or piece of rock, which could be even provisionally identified as Cretaceous in age, has been found there.

The character of this Cretaceous material is identical with that which is found in connection with the moraine throughout Long Island and the islands to the eastward, consisting of ferruginous shaly fragments, or concretionary nodules of hardened clay or marl, due to oxidation of the included iron salts or to the formation of limonite layers over the exterior. The lithologic character of this material, even in the absence of any palæontologic evidence, is so peculiar that once recognized it can not be mistaken for anything else. It evidently represents fragments of clay or marl which have been torn up and included in the moraine, after which it became oxidized and hardened into the condition in which we now find it.

Attention should also be called to the significance of the occurrence of marl fossils at Clifton, indicating beyond doubt that the marl belt, which now has its farthest eastward exposure in New Jersey, at the Atlantic Highlands, must originally have extended across the Lower Bay to Staten Island and occupied part of what is now New York Harbor. This fact gives us the connecting link between what we know of the outcrop of New Jersey and what we infer in regard to its eastern extension, from the occurrence of similar fossils in the moraine of Brooklyn, Montauk Point, Block Island and Martha's Vineyard. Thus far, however, no exposure of marl strata has been found on Staten Island.

Finally, it is of interest to note the relation which the moraine bears to the underlying or pre-glacial topography. Apparently the serpentine ridge served as a more or less effective barrier to the advance of the ice, as indicated by the morainal sinus immediately south of the highest point of the ridge, from whence the ice was deflected eastward towards Fort Wadsworth and southward toward Prince's Bay, forming the lobes in the moraine at those localities and protecting the plain region between by checking the further advance of the ice in that direction.

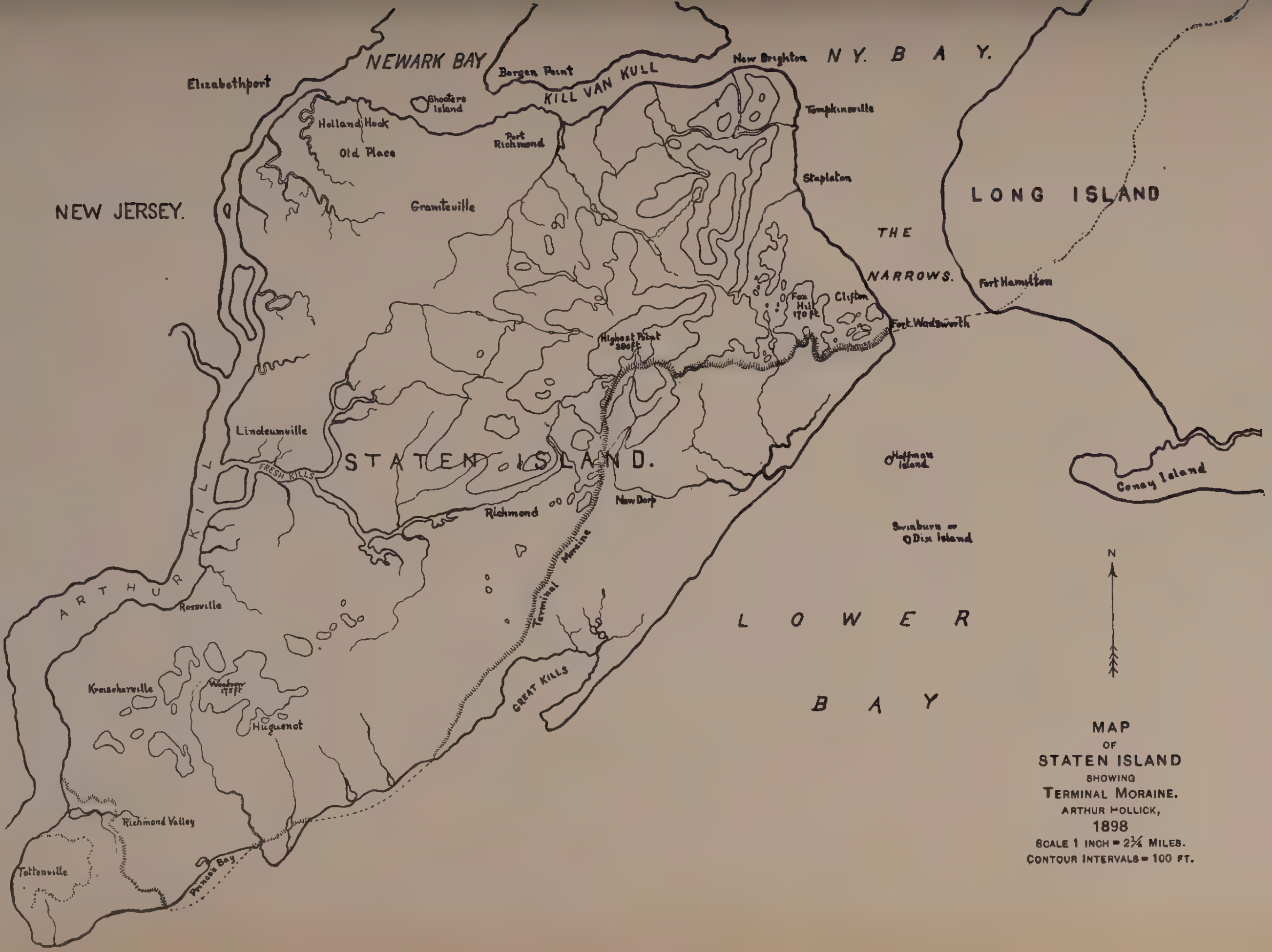
Columbia University,
October, 1898.

PLATE I.

PLATE I.

TERMINAL MORAINE ON STATEN ISLAND.

The terminal moraine is indicated by hachure when known, by dotted lines where inferred.



MAP
OF
STATEN ISLAND
SHOWING
TERMINAL MORAINE.
ARTHUR HOLLICK,
1898
SCALE 1 INCH = 2¼ MILES.
CONTOUR INTERVALS = 100 FT.

[Annals N. Y. Acad. Sci., Vol. XII, No. 5, pp. 103 to 118, July 7, 1899.]

DEVELOPMENT OF THE OSSICULA AUDITA IN THE OPOSSUM.

Richard Weil.

(Read November 19, 1898.)

[Plates II and III.]

The following is a preliminary report on the development of the ear-bones in the Trinidad Opossum. Owing to a lack of the proper stages of the anatomical material, the present notice will deal only with the development of the malleus and incus.

Up to the present time, November, 1898, only the higher Mammalia have been investigated with regard to the development of these bones. Meckel, in 1820, first described the embryological continuity of the malleus with the first visceral, or mandibular, arch, and this statement has since that date never been overthrown. The question remains: does the incus arise from the first arch, or from the second, or independently?

The history of the evidence is briefly as follows: Valentin and Rathke (1835) were the first to maintain the origin of the incus from the first arch, that is to say, its embryonic continuity with the malleus. This view was firmly established in 1838 by Reichert, whose conclusions were verified and amplified by Huxley (1858). In 1869, however, Professor Huxley was induced, by his discovery of a direct union by means of cartilage of the stylo-hyal with the columella in *Sphenodon,* to believe that the embryonic appearances had been misinterpreted by Reichert, and that the incus was actually a derivative of the hyoidean arch. This view was taken up by Parker, and received full confirmation from his embryological researches (1874, 1877), and other and later researches by English investigators, noticeably Fraser, have successively accumulated the evidence for this theory. On the other hand, German authority since the time of Reichert has been unanimous in declaring the incus to be derived from the first, or mandibular arch. With reference to these long-standing and apparently irreconcilable discrepancies, the following statement of Fraser, who made sections in three planes of a large number of forms, is deserving of particular attention. He says : "I soon learned that the incus was quite as distinct from both cartilages (mandibular and hyoidean) when they could properly be called so, as it was at birth or at adult age, so that I had to work upon embryos at a stage preceding the true cartilaginous one, that is, at a stage between that in which there was not the slightest trace of cartilage to be detected, and that in which the cartilages of the arches were sharply and clearly defined, and in which the cartilage cells had acquired a characteristic hyaline structure. But here again the difficulty arose that although the cartilages could be roughly distinguished, yet they were not limited by any sharp line of demarcation, but faded gradually away into the adjacent mesoblastic or embryonic tissue, from which they differed only in the greater aggregation of round cells."

Two years ago, as I reported to the Academy, an investigation of sections of a full series of Pig embryos, induced me likewise to conclude that it was impossible from the material employed to decide with certainty as to the origin of the incus.

DIDELPHYS MURINA.

Up to the present time, no investigation into the ossicula of the Marsupialia by means of the newer methods has been recorded. In the *Berliner Monatsberichte* for 1867 there is a note to the effect that Professor Peters found in certain young Marsupialia, including *Didelphys*, that the os tympanicum was continuous with Meckel's cartilage. This was in support of his theory that the quadrate of lower vertebrata is to be sought in the tympanic bone of Mammals. Upon this point, however, Peters was led astray, doubtless on account of the minuteness of the object under observation and the lack of the more perfect modern method of sectioning. In my sections I find that the tympanic bone is not yet formed, its future position being indicated, however, by a definite mass of cells, situated between the eustachian tube and the gelatinous anlage of the meatus auditorius externus, and just below the anlage of the membrana tympani (Plate II). Secondly, Professor Minot quotes Parker to the effect that an investigation of the Marsupialia had convinced him of the error of his previous opinions, since the incus was here without any doubt continuous with the mandibular arch. Parker's investigations upon this point have, however, never been published; as far as Parker ventures in the brief statement above referred to, my observations perfectly coincide with his.

The material at my disposal consisted of three Opossums of the species, *Didelphys murina* of Trinidad.[1] One of these, the largest, was of no service in the research, as the sections revealed that the ear-bones had already assumed their adult relations. The other two, coming from one litter, were of the same size, and represented identically the same stage of development. They were taken from the pouch, but measured in length no more than six to seven millimeters. The length of the head from the tip of the snout to the external ear was two to three millimeters. Sections of the thickness of seven μ were cut with the Minot microtome, and the complete series mounted. In order to demonstrate the relations of the cartilages, a model of the ear bones of the left side was made, in which all their dimensions were multiplied by 175. The method here employed was a slight modification of that recommended by His.

An understanding of the general topographical relations may be gained from an inspection of the figure of the model, the following description being added merely as commentary. From the distal extremity Meckel's cartilage passes up on each side at an angle of about 30° to the base of the skull, lying inwards of the anlage of the dentary, to which it contributes in the usual manner. The shape of the cartilage towards the symphysis is rounded but as the sections run back, it is seen to increase very materially in size, and to assume the oval form seen in the model (Plate III., Fig. 2). Beyond the dentary, it continues for a short distance, unchanged in shape or direction, then gradually bulges out at the end directed towards the base of the skull, and a little later bends down at a sharp angle as in the Pig. This highly differentiated portion without any doubt represents the malleus ; in it may be distinguished, as seen in the model, head (capitulum), neck (cervix), the processus gracilis, and the manubrium. Furthermore it has all the important relations of that bone, impinging on the tympanic membrane, articulated with the incus, etc. In direct continuity with it at some points, but already splitting off from it in others, is a relatively small cartilage, the incus. The articulation between these two elements is of the same nature as that found in the adult marsupial, and contrasts strongly with the ball and socket joint of higher mammals. In the incus, the long crus to which the stapes is articulated, and the short crus, contributed as in higher mammalia by the auditory capsule (Dreyfuss), are easily to be distinguished. The stapes is a single element, which comes into relation both with the mandibular arch, through the long crus of the incus, and with the periotic capsule. The stapes here appears as an imperforate plate, and the characteristic stapedial branch of the carotid is lacking, so that the cause of its eventual perforation in the adult still remains obscure. The hyoidean is attached, not as in the Pig, in the proximity of the ear bones, but a measurable distance below them, so that this fruitful source of error and confusion is eliminated.

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[1] I am happy to make acknowledgement of the courtesy of Dr. Chapman and Professor Allen to whom I owe this material.

In a general way, the stage of development of the head is indicated by the fact that the only bone present is the dentary.

As regards the ossicula audita, the condition of the anlage is very extraordinary, and presents a parallel with no stage found in the Placentalia. The cartilage of the bones in question is already well formed, and their shape is accurately defined, as in the Pig of from two to three inches, but in their relations to other cartilages they present a far more embryonic condition than is found even in the early stages in which these elements can be made out in the Pig embryo, as above described.

As regards the anatomical relations of the malleus, this investigation serves merely to confirm the now almost universal opinion that the malleus is a derivative of the mandibular arch. As in the higher mammalia, it continues Meckel's cartilage without a break, the cartilage throughout being well developed.

The relation of the head of the malleus with the body of the incus is, however, entirely different from anything yet found in the embryos of the higher forms. The process of segmentation of the incus from the malleus has already begun, but cellular continuity is in certain places still plainly to be made out. This continuity is not by means of histologically indifferent tissue, but by tissues sharply separated from the neighboring undifferentiated mesoblast. The connecting cells are, in fact, cartilage cells, though only in the first stage of their development (see Plate III., Fig. 1, also Plate II).

It is apparent, therefore, that the incus is to be regarded, as the Germans have so long contended, in the light of a descendant of the mandibular arch. With the hyoidean arch it has absolutely no relation. The derivation of the short crus from the labyrinth wall, already noticed by Dreyfuss in some of the higher forms, is present also in the Opossum (Plate II.). Its significance is still problematical.

This investigation was suggested to me by Professor Osborn, and was carried on during the year 1896 in the Zoölogical Laboratory of Columbia University.

PLATE II.

PLATE II.

EAR BONES OF OPOSSUM.

Part of a vertical section of the skull, running through the middle ear. Multiplied 300 times.

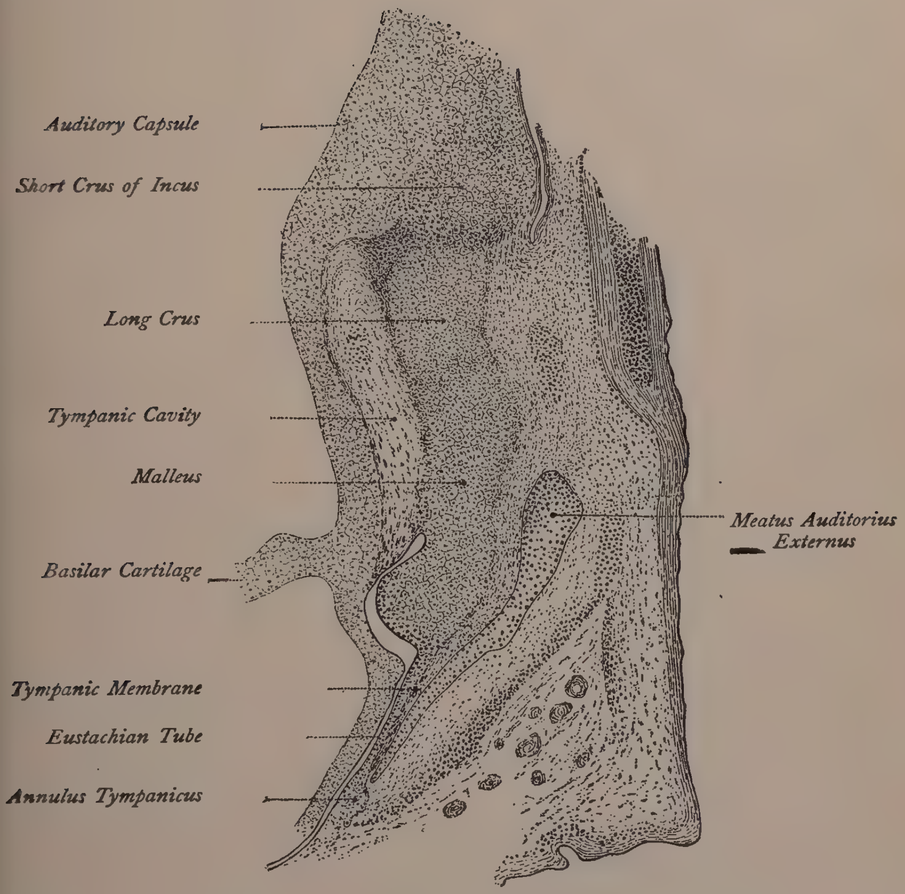
Auditory Capsule
Short Crus of Incus
Long Crus
Tympanic Cavity
Malleus
Basilar Cartilage
Tympanic Membrane
Eustachian Tube
Annulus Tympanicus
Meatus Auditorius Externus

PLATE III.

PLATE III.

EAR BONES OF OPPOSSUM.

FIG. 1.—Section of malleus and body of incus. Drawn with Abbe's camera lucida, multiplied 200 times.

FIG. 2.—Model of ear bones, multiplied 175 times. The model was made in three pieces, although segmentation was not yet complete. The lines of future division are, however, very distinctly indicated in the sections, as seen in Plate III, Fig. 1.

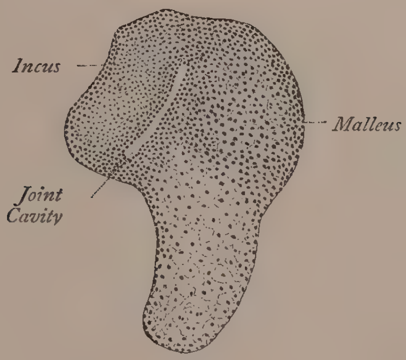
Incus
Malleus
Joint Cavity

FIG. 1.

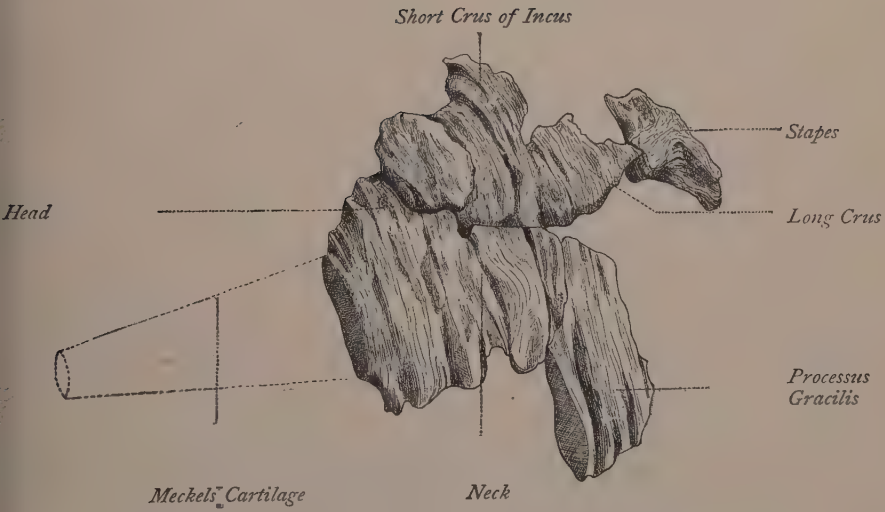
Short Crus of Incus
Stapes
Head
Long Crus
Processus Gracilis
Meckels' Cartilage
Neck

FIG. 2.

[ANNALS N. Y. ACAD. SCI., Vol. XII, No. 6, pp. 113 to 116, July 8, 1899.]

ORIGIN OF THE WHITE AND VARIEGATED CLAYS OF THE NORTH SHORE OF LONG ISLAND.

BY FREDERICK J. H. MERRILL.

(Read January 19, 1899.)

IN 1883, during a study of the Cretaceous and Tertiary clays of the north shore of Long Island, the writer became interested in finding a solution of the problem of their origin. Through the last fifteen years various items of geologic evidence have been carefully collected which, with the help of chemical analysis, make it possible to present a satisfactory demonstration of the fact that the white and variegated clays in question are derived from the residuum of the crystalline limestone of Lower Silurian age which forms an important part of the crystalline terrane of Westchester county, N. Y. and, by its solution in connection with subsidence of the land, has given existence to the navigable channels which surround Manhattan Island and to the great waterway of Long Island Sound.

In 1889 the attention of this Academy was drawn to the occurrence of some highly colored material resembling clay which had been observed in Morrisania in excavating for the readjustment of the railroad tracks. Dr. D. S. Martin collected some specimens of this which were exhibited to the academy in connection with a paper read jointly by Dr. Martin and myself.[1]

In this paper it was shown that the seeming clays were residual products from the decomposition of the crystalline limestone which underlies the valley occupied by the tracks of the New York and Harlem Railroad Co. A few years later, Professor Kemp called attention to some specimens of similar material from the Blackwell's Island tunnel, the bottom of the channel on either side of the island being underlain by decomposed material resembling a kaolin.

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[1] Ref. *Trans. N. Y. Acad. Sci.*, Vol. IX, p. 45-46, 1889.

This material I recognized to be similar to that collected by Dr. Martin in Morrisania. Subsequently in making a detailed study of the geology of Manhattan Island, I had occasion to investigate the material of the bottom of the East and North Rivers.

My first visit was to the office of the engineer of the Dock Department where I ascertained that a whitish material like kaolin had been found at many points on the bottom of the East and North Rivers. Then going to the office of Colonel Gillespie, in charge of the harbor improvements, I found samples of similar material from the East River near the foot of 10th street and from the "middle ground" near Astoria. Further effort put me in possession of some material from the latter place where dredging was going on.

It then seemed desirable to make a chemical examination of this residual material and this work was placed in the hands of Dr. H. C. Bowen of New York. The results of the analyses are given in the following table.

These analyses show a very close relation in chemical composition between the white and variegated clays of the North Shore of Long Island, of which those from Elm Point and Eaton's Neck may be regarded as types, and the residual products of the decay of the metamorphosed Palæozoic limestone of New York and Westchester counties.

A geologic study of the shores of Long Island Sound and the adjacent territory shows that the prevailing rock on the north shore of that territory is the Manhattan schist, a metamorphosed representative of the Hudson River group and that on Long Island wherever solid rock is found beneath the loose deposits of mesozoic and cenozoic age, it is a banded gneiss, identical in lithologic character with that which has been determined to be Precambrian on New York Island and in Westchester County.[1]

This may be regarded as conclusive evidence that the former rock which occupied the site of Long Island Sound was the crystalline dolomite which has been recognized as a metamorphic limestone of Lower Silurian age.

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[1] See Fiftieth Annual Report, N. Y. State Museum, 1896, pp. 21–31.

The inference from the facts presented and, indeed, the well-founded conclusion, is that the portion of Long Island Sound which borders Westchester County owes its origin in part to the solution of a limestone which once occupied that place and that the white and variegated clays of Long Island, some of which have been regarded as of Cretaceous age on account of the leaf prints contained in them, are accumulated residues from the solution of that limestone under atmospheric agencies.

How large a portion of Long Island Sound owes the formation of its depression to mechanical solution in the manner suggested, cannot be determined in the light of present knowledge, but it is probably safe to conclude that so far eastward as the Palæozoic rocks extend beyond the New York and Connecticut boundary, these causes have had a controlling influence.

The large granite area east of New Haven is regarded by those who have given it most attention, as Precambrian, but this is known to exist only along the northern margin of Long Island Sound and it is entirely possible that to the southward of these Precambrian rocks extended a large Palæozoic limestone area occupying the site of the present channel of the Sound and which, by solution, has disappeared.

We have at present no definite record of the occurrence of the white and variegated clays on Long Island to the eastward of Eaton's Neck where they are now found quite near the surface. However, as they have been observed on Block Island and Martha's Vineyard, it is possible that the deposit is continuous.

Analyses of Limestones, Limestone Residues and Clays.

	1 Inwood Limestone.	2 Mott Haven Limestone.	3 Morrisania Limestone.	4 "Middle Ground" Limestone.	5 Residue of No. 4. Artificial.	6 Residue of No. 4. Natural.	7 Nat Res. Blackwell's I. Tunnel.	8 Nat. Res. Morrisania Black.	9 Clay Eaton's Neck	10 Clay Elm Point.
CaO	25.34	27.81	30.88	31.08	3.07	0.76	0.78	1.00	0.67	0.59
MgO	7.74	10.32	22.05	21.53	11.17	0.26	8.65	tr.	0.07	0.11
Al_2O_3	13.63	13.25	0.42	1.21	16.21	24 18	23.81	22.99	22.33	15.17
FeO			tr.	tr.				0.71	1.38	1.24
Fe_2O_3	1.33	1.96				4.53	5.40			
SiO_2	17.21	7.77	0.58	0.55	61.71	56.58	48.15	51.96	66.46	76.50
P_2O_5	.15	.25				0.10	0 07	tr.	0.10	0.07
CO_2	34.61	38.68	46.64	45.12						
Na_2O						0.91	0.63		0.58	0.81
K_2O						2.43	0.66		1.52	1.27
SO_3	.15	.30	0.06	0.10		1.61	3.88			
C								7.44		
H_2O-250° F.					0.03	0.23	0.10	0.15	0.31	0.12
H_2O comb.					1.97	6.08	7.03	16.25	6.21	4.27
Mn	tr.	tr.				tr.				
Cl						0.44				
	100.16	100.34	100.63	99.59	94.16	98.11	99.16	100.50	99.63	100.15

[ANNALS N. Y. ACAD. SCI., Vol. XII, No. 7, pp. 117 to 138, July 8, 1899.]

FURTHER NOTES ON THE ECHINODERMS OF BERMUDA.

HUBERT LYMAN CLARK.

(Read March 13, 1899.)

[Plate IV.]

ONCE more I am indebted to Professor Bristol for the privilege of examining a collection of echinoderms, made in Bermuda by students of New York University, and it has proved of even greater interest than the one made in 1897. The value of the collection made in 1898 is very greatly increased by the care taken in the preservation of the specimens, and especially by the valuable field notes made by Mr. C. E. Brush, Jr., and Mr. F. W. Carpenter, and I wish to express my thanks to these gentlemen for their courtesy in turning their notes over to me for my use. The chief interest in the collection centers on the holothurians, especially on the Synaptidæ, of which there are five species. Only one of these has previously been recorded from Bermuda, while one of the others is apparently new to science. Most of the holothurians are remarkably well preserved and some are as well extended as in life.

The collection contains only two ECHINOIDS and both of these have been recorded from the islands before. They are *Echinometra subangularis* (Lecke) and *Mellita sexforis* A. Ag. The former are reported as common on both the north and south shores but in color those from the north shore are "rich dark red" while those from the south are said to be "jet black." There are two very good specimens of *Mellita* "dredged in eight feet of water at the entrance to Flatt's Reach, just off Giblet Island, on sandy, non-shelly bottom." According to Mr. Brush's field notes they were *brown* when alive, while the specimens I have collected in Jamaica were a delicate *olive green.*

There are four species of OPHIURIDS in the collection and these also have all been collected in Bermuda previously. One of these, *Ophiocoma echinata* (Lamk.) (= *O. crassispina* Say), was previously known from Bermuda from only a single specimen, but there are eleven before me, one taken in Harrington Sound and the rest along the north shore "about a quarter of a mile southwest from Seaward." There are also three specimens of *Ophiocoma pumila* Ltk. each with six arms, collected in Castle Harbor and Bailey's Bay, a single *Ophiura appressa* Say from Bailey's Bay and a very large number of *Ophionereis reticulata* (Say) from the same place. The last one, said to be very common, occurring in "bunches partially buried in the sand."

There are only two ASTEROIDS in the collection but one of these is of special interest as it is an addition to the fauna of Bermuda. This is *Luidia clathrata* (Say) of which there is a single very fine specimen, dredged off the north side of Trunk Island, Harrington Sound, in one or two fathoms of water, the bottom being of clear white sand. Mr. Brush says in his notes: "This starfish must have been buried in the sand in order to have been broken by the dredge, as the latter was slung so that it scooped up about three and one-half inches of sand. I found from inquiry among the natives that this species is only fairly common and that it buries itself in the sand. Its presence is denoted by five furrows in the sand, converging to a single central point. This of course may be an error." The most remarkable thing about the specimen is its color. Mr. Brush says that in life it was *salmon pink;* in alcohol this has bleached to a creamy white. All of the specimens of *clathrata* which I have hitherto seen are bluish-gray, quite dark on the center of the disc and along the aboral side of the arms, and I thought the specimen from Bermuda might prove to be a distinct species. Unfortunately I have no good specimens of *clathrata* available for comparison, but so far as I can judge from descriptions and from such material as is available, there is no difference aside from color between the specimen from Bermuda, and typical *clathrata.* The other starfish in the collection is the small pentagonal form *Asterina folium* (Ltk.) which has been reported from the Bermudas twice before. Mr. Brush, however, says that this specimen was collected "in the channel connecting the two small lagoons in Coney Island. This is the first time we have found this species in any place but the spit in Castle Harbor to the east of Waterloo."

The collection is rich in holothurians, with more than fifty specimens representing, almost beyond doubt, every species hitherto collected in Bermuda and adding several others to the list. The most prominent of these animals, because of their large size, are seven specimens of *Stichopus*, two representing the black form named *diaboli* by Professor Heilprin[2] and the rest the spotted form which he called *xanthomela.* The comparison of these specimens with each other and with specimens of *Stichopus* from Jamaica has confirmed the opinion expressed last year,[1] that *xanthomela* is a synonym of *möbii* Semp. and has made me very doubtful of the standing of *diaboli* as a good species. While the question can only be settled by a careful study of the animals in life, there are several reasons for thinking that *möbii* will prove to be immature individuals of *diaboli.* Professor Heilprin separated the two forms for four reasons (to judge from his descriptions): (1) the difference in color; (2) the size of the dorsal papillæ; (3) the fineness of the filaments in the genital bundles; (4) the number of tentacles. Regarding the difference in color neither Professor Heilprin's account nor Mr. Carpenter's field notes, nor the specimens before me from Bermuda, give any hint of intergradation. But in a large series of *Stichopus* collected and studied in Jamaica almost every possible gradation from reddish yellow without a spot, to jet black without a light mark anywhere, was found. Moreover, as a rule the dark forms were larger and, generally, the larger the specimen the more uniformly dark it would be. In the matter of the dorsal papillae, in the alcoholic specimens from Bermuda, there is no real distinction between the condition in the black and that in the spotted form. In Jamaica there was considerable variety noticed in this particular, though it was not so marked as in the matter of color. My observations on the genital organs do not accord with those of Professor Heilprin for I was unable to see that the "filamental processes" are to any important degree finer in one form than in the other; what slight difference there was seemed to me indicated that the filaments were *coarser* and less numerous in the spotted form. Finally, regarding the number of tentacles, my specimens from Bermuda differ from Professor Heilprin's. Both those examined last year and four of the five spotted ones in this year's collection have twenty tentacles, the remaining one having nineteen. Each of the black ones has twenty. Apparently the specimens examined by Professor Heilprin and the specimen collected at Bermuda[5] by the "Challenger" were exceptional. I have tried in vain to find some characteristic in the calcareous particles of the body wall or in the calcareous ring, which would serve to distinguish the two forms, but entirely without success. I have not found the larger tables which Theél found in his specimen of *möbii* from Bermuda, though it would be absurd to say that there are none present. The calcareous ring varies more or less in different individuals but where best developed, it is markedly *asymmetrical* (as Theél described it in *S. japonicus*)[5] that is the dorsal pieces are much stouter than the ventral, and the dorsal radial pieces have posterior prolongations. Both Professor Heilprin and Mr. Carpenter say that the spotted form is somewhat smaller and very much more scarce. Mr. Carpenter says of the two forms: "The large black holothurian (*Stichopus diaboli*) is exceedingly abundant in the water of Castle Harbor and Harrington Sound and along the outer shores of the island, within the reef. Wherever the white, sandy bottom, which is sometimes more or less overgrown with seaweed, can be seen, there *Stichopus* is sure to be detected. The large spotted form is much more rare. Living under the same general conditions alongside of the uniformly black *Stichopus*, its occurrence is to that of the latter, roughly as 1 to 60." The above facts seem to show that the only real difference between the two forms is in the color, and it would be a cause of some surprise if intergradations cannot be found. It seems to me that the smaller size of the spotted form and the occasional absence of one or two tentacles may be indications of immaturity. We know nothing of the breeding habits of this species, but if the early period of life were passed in deep water or on a different bottom from that where the adults are found, the relative scarcity of the spotted form would be easily accounted for. The whole question offers a fascinating field of inquiry for the zoölogist fortunate enough to spend some weeks on the island. Since, however the intergrading forms have not been found, *diaboli* must for the present stand as a recognizable species.

There are more than twenty specimens, of varying size, of the small holothurian, which was identified last year[1] with *H. surinamensis* Ludw. A careful examination of these and comparison with specimens of *surinamensis* from Jamaica has convinced me that the form from Bermuda cannot properly be separated from that species. The only constant difference which I can find is in the absence from the *body-wall* of the "bars" which are present as supporting rods in the pedicels and papillæ. It might easily be supposed from Ludwig's description[3] that in his specimens these bars were present only as supporting rods, but Theél[5] found them in the body-wall of specimens from Mexico, and in my Jamaica specimens they are present, though few and far between. I have not found them in a single one of the specimens from Bermuda, but it is not impossible that they may be present. But even if they are not, it does not seem to me that that fact would justify the formation of a new species. The calcareous tables are like those figured by Ludwig and are very numerous, but in the pedicels and papillæ they have usually a well-developed disc, the edge of which is not smooth, but rather irregular and with a number of spiny projections. These tables also have more teeth (18–20) at the apex than the common tables of the body-wall. This is true of Jamaica specimens as well as those from Bermuda. The radial pieces of the calcareous ring are not exactly like Ludwig's figure, being wider than they are high, and not overtopping the interradial pieces so much. The pedicels are irregularly scattered and are comparatively few in number, averaging from 12–15 per sq. cm., while the papillæ are even less numerous, averaging in the same individuals, 6–12 per sq. cm. The largest specimen before me is 170 mm. long by 23 mm. in thickness; the smallest is 40 mm. by 14 mm. The color of the alcoholic specimens is brown, indistinctly marked with spots and blotches of black; the pedicels are yellow especially at the tip; the tentacles are yellow; the body-wall is thin. In formalin specimens the body-wall is thick, the ground color is much lighter and the pedicels and tentacles are almost white. One of the alcoholic specimens is lighter than the others and very strongly tinged with yellow. Mr. Carpenter says in his field notes on this species: "Color, a general brown in varying shades. Several specimens have a darker color approaching black. Can be picked up almost anywhere along the reef-protected shore after a little search among the broken rocks." The twenty-one specimens which are in proper condition for a thorough examination showed an interesting diversity in the number of tentacles and Polian vesicles:

2	had	21	tentacles.		3	had	1	Polian	vesicle.
13	"	20	"		8	"	2	"	"
3	"	19	"		5	"	3	"	"
1	"	18	"		3	"	4	"	"
1	"	15	"		1	"	5	"	"
1	"	12 (?)	"		1	"	8	"	"

The specimens with twelve and fifteen tentacles were very much contracted and I could not be positive of the number but it was certainly much smaller than normal. The stone canal was always single and, except in two cases, free. It was sometimes very small but in one specimen it was 4 mm. long and distinctly pear-shaped. Cuvier's organs were present in a few individuals but in most cases they had either been discharged or were never present. After a careful study of Professor Heilprin's description [2] and figures, I am convinced that the form which he identified as *H. floridana* Pourt. is really this species, *surinamensis*. The reasons for this conclusion are as follows: There is nothing in his description which will not apply to *surinamensis*, while his figures of the stools and his comment on their variability apply perfectly to that species. Moreover, he neither mentions nor figures the "rosettes," which are so very characteristic of, and noticeable in *floridana* and the holothurians of that group. The diversity in the number of tentacles, the "distinctly papillate" dorsal surface and the irregular distribution of the "elongated yellowish pedicels," all point to *surinamensis*. Finally it is hardly probable that *floridana* should be common enough in 1888 for Professor Heilprin's party to collect five specimens, while in 1897 and 1898 not a single individual could be found by the New York University students. And since *surinamensis* is obviously the common holothurian of the Bermudas, it is not likely it would have entirely escaped the notice of the Philadelphia party. These reasons to me are sufficient for striking *floridana* from the list of Bermudan holothurians.

There are seven specimens of the holothurian which was identified from two specimens in the collection last year,[1] as *Cucumaria punctata* Ludw. Several of these are beautifully preserved, thanks to Mr. Carpenter's skill, and the tentacles and pedicels are as well extended as in life. A careful study of these specimens has confirmed their identity and led me to the conclusion that *Semperia bermudensis* Heilp. must be considered a synonym of *Cucumaria punctata* Ludw. The seven specimens before me vary in size from 40 mm. by 15 to 70 mm. by 25. The tentacles are ten in number and are arranged either as nine long and one short, or seven long and three short, or one very long, three on each side medium and three short, or all approximately equal. The variation in the number of Polian vesicles is also notable. Four specimens have one each, two have two each and one has three. The stone-canal is single and usually in the mesentary but sometimes the end is free. The genital bundles have numerous (40–50) undivided filaments, yellow or orange in color, and three or four centimeters long. The vent is more or less rayed and one specimen seems to have anal teeth but the presence or absence of the latter seems to be only a question of the more or less calcifying of the largest anal papillæ. In alcoholic specimens the color is whitish, very thickly spotted and mottled with dark purplish gray; some specimens have a strongly yellow tinge. Mr. Carpenter says in his notes on this species: " Certainly not of a common variety. Found in but one place; under loose slabs of rock on north shore just southwest of Bailey's Bay. Color of body ranging from yellowish-brown to dark blue. Color of numerous and prominent tube-feet grayish-yellow." Professor Heilprin[2] based his new species, *Semperia bermudensis*, upon a single specimen collected on the north shore west of Flatts' village. He distinguished it from *C. punctata* Ludw. on account of (1) the different color, (2) the different arrangement of the tentacles, (3) the number of Polian vesicles, and (4) the number of filaments composing the genital bundles. After what has been said above it hardly seems necessary to state that these characteristics are more or less variable, and while one of my specimens is exactly like Ludwig's[3] type, another is almost as nearly like Heilprin's. *Semperia bermudensis* must therefore be reduced from the list of valid species to the already crowded ranks of synonyms.

The collection of 1898 contains four specimens of a small holothurian not represented in the collection of 1897. These four were in the same bottle with *H. surinamensis* and were apparently not distinguished from that species by the collector. They came from the same localities but were probably less common than that form. The alcoholic specimens are easily picked out from those of *surinamensis* by the position of the anus, the flattened ventral surface, the tendency of the feet to form regular longitudinal series and the color. They were readily identified as *H. captiva* Ludw., the large bright yellow bunch of Cuvierian tubes being very noticeable. It is attached well up on the respiratory tree some little distance from the cloaca. Papillæ are quite numerous and prominent on the dorsal surface. Pedicels are numerous on the middle and rear of the ventral surface, indistinctly arranged in three series. The specimens vary in size from 30 mm. by 12 to 70 mm. by 20 mm. Stone canal single and Polian vesicles one or two. The genital organs are present in only a single individual and consist of a small bunch of two or three dichotomously branched tubules attached to the mesentery very near the mouth. The anus is on the dorsal side or terminal close to the dorsal surface. The calcareous ring is like Ludwig's[3] figure for *H. captiva* but the calcareous tables and buttons resemble more closely Heilprin's[2] figures for *H. abbreviata*. After comparing the figures and description of the latter species with Ludwig's description and figures of *H. captiva* and with the four specimens before me, I am confident that the two species are identical. One of my specimens agrees in every detail except the shade of color and the number of tentacles with the type of *abbreviata*, yet cannot properly be separated from the other three. Accordingly I have stricken *H. abbreviata* from the list of Bermudan holothurians.

The rest of the collection before me is made up of fourteen synaptids, thirteen of which were in a single bottle labeled "Synaptas." Of these Mr. Carpenter says: "Collected at Cove, Coney Island, June 28, 1898. The cove, which opens on the submerged reefs of the north shore by a narrow channel through the rocks, is well protected from the waves. In the sandy bottom of this cove less than eight inches below the surface of the sand, the Synaptas were found. Bottom of cove covered with water even at low tide. Synaptas cylindrical in shape varying in length from half an inch to about five inches, when found. Diameter never exceeded half an inch. Color of body a light brown, modified by the color of the sand which filled the intestine of each. We found the Synaptas in but one place. However this was the only spot where we looked for them carefully. We found them on an average I should say of one to every three shovelfuls of sand sifted." The other synapta was in a small bottle by itself and of this one Mr. Carpenter says: "Collected at Cove, Coney Island, July 28, 1898. Found under a stone in a tideway through which water constantly runs but never with great rapidity. Surroundings rocky. Specimen was of uniform cylindrical shape and about one inch long and one-eighth inch in diameter. When undisturbed tentacles were extended and seemed to assist in locomotion. Color, reddish-brown with longitudinal markings some darker and some lighter than ground color of body. I considered this specimen a 'find.' It was the only one we came across." This single individual proves to be a small specimen of *Synapta vivipara* (Oerst.) which has been recorded from the Bermudas before. It agrees in all particulars with specimens from Jamaica, except that there are only eleven tentacles. In the body cavity were three very young embryos, in which the hydrocœl was just formed. The situation in which the specimen was found is quite remarkable, since, in Jamaica, *vivipara* always occurs in bunches of a peculiar seaweed sometimes growing on sandy or muddy bottom but especially on the roots of mangroves.

The other thirteen synaptids represent four distinct species. There are two specimens of *Chiridota rotifera* (Pourt.) previously known from Florida, Jamaica and Brazil, but not hitherto recorded from Bermuda. The specimens are both large and similar to specimens from Jamaica, but are slightly different in color having a decidedly yellow tinge. There is a single very small specimen (16 mm. long) of *S. inhærens*, easily recognized by the characteristics of the calcareous ring and miliary granules. as well as its pure white color. This species though widely distributed throughout the north Atlantic has not been recorded previously from Bermuda. *Synapta roseola* (Ver.) is represented by five specimens, distinguished by their reddish or yellowish color but really identified by the calcareous ring and miliary granules peculiar to that species. They agree in all particulars with specimens from the New England coast, hitherto the only locality from which the species has been recorded.

The remaining five specimens consist of two whole synaptas and fragments of three others, entirely different from any species hitherto described. In size this new species agrees with *S. inhærens*, the largest specimen being about 175 mm. long. The color is somewhat rosy, the prominent verrucæ being well supplied with the reddish pigment so abundant in *S. roseola*. The verrucæ are quite numerous, over 500 to the square centimeter, though the number per square centimeter would of course be greatly increased by increased contraction of the body wall. There are twelve tentacles, each with from 15–19 digits, and on the inner side of each near the base are numerous (25–30 or more) "sense-cups" similar to but somewhat smaller than those found in *inhærens*. There is no trace of eye spots. The genital papilla is in the mid-dorsal line just outside of the tentacles and in one specimen is very prominent, half a millimeter long. The reproductive organs are only slightly developed in these specimens, the branches being only 10 mm. long. The latter are very slender and lie on both sides of the dorsal mesentery. The stone-canal is small and single and lies in the mesentery. The Polian vesicles are fairly numerous, two long ones (8 mm.) and three short (½ mm.) in the largest specimen, two long and one short in the other. The longitudinal muscles of the body wall are very prominent. The alimentary canal is almost straight so that the mesentery which supports it is confined to the mid-dorsal interradius. The œsophagus is wide and the stomach is quite prominent (Fig. 13). The hæmal system is very noticeable on the latter and on the intestine also. The ciliated funnels are of two kinds (Figs. 11 and 12) and occur not only near the mesentery in the mid-dorsal interradius, but, in the left dorsal interradius, they form a prominent line over 100 mm. long. The large ones are comparatively few but the small ones are crowded. The former are about 1.1 mm. long and .500 mm. wide, while the latter are only .110 mm. long but are .133 mm. wide. In length both sorts of funnel are about equal to the corresponding ones in *inhærens*, but they are much wider so that the proportions are quite different. Their shape and proportions can be best understood from the figures. There is no cartilaginous ring. The calcareous ring (Fig. 10) is narrow and its pieces are wide so that their relative proportions are quite different from *inhærens*. Moreover the opening for the passage of the radial nerve is very wide and narrow instead of circular, and is slightly overarched by the main body of the radial piece. The anchors and plates are of two kinds very different from each other in size and shape.

The smaller ones are found chiefly at the anterior end of the body where they are fairly numerous, about 350 or so per square centimeter in a normally contracted specimen ; near the rear end there are only about twenty-five or so per square centimeter. The larger ones are found only near the middle and posterior end of the animal ; they occur about 215 or so per square centimeter near the middle but further back are not so numerous, about 125 or so per square centimeter. The smaller anchors (Fig. 3) are about equal in size to the ordinary anchors of *inhærens*, measuring about 188 μ long. The arms are short and thick and quite smooth. A few abnormal ones have a third arm projecting in front (Fig. 5). The posterior end is not at all branched but is simple and very finely toothed. The plates accompanying these anchors are somewhat like the ordinary plates of *inhærens*. They measure about 166 μ × 125 μ and have seven large, toothed holes, and numerous small smooth holes at the narrower end (Fig. 4). The bow is not arched out of the plane of the plate, and is only present in part, the center being fused with the plate itself as will be seen in the figures. One curious double plate was found, accompanied by twin anchors (Fig. 6). The large anchors (Fig. 1) are about three times as long as the small ones, though they vary greatly in size. A few are only about 300 μ in length but the great majority are over 500 μ and many are over 700 μ. The largest one measured was 733 μ long. The posterior end is not at all branched but is finely toothed. The arms are long and slender and each has about eight teeth on the outer side, the points of the teeth turning upward away from the tip of the arm. The plates accompanying these anchors (Fig. 2) vary greatly in size but are always much longer than broad and are usually much shorter than the anchors. Most of them are from 300 μ to 400 μ in length but many are nearly 500 μ. The largest one measured was 510 μ long by 260 μ broad. These plates have from ten to thirteen large, toothed holes arranged in three longitudinal rows, and numerous small, smooth, holes at the posterior end, which is often nearly square, though generally the corners are rounded. The bow is merged into the plate itself as in the smaller plates. The miliary granules (Fig. 7) are very numerous and are not confined to the longitudinal muscles, nor to special patches, but are pretty uniformly distributed over the body. They are nearly all more or less C-shaped and measure about 22 μ long, those near the posterior end of the body (Fig. 8) being a trifle the largest. In the tentacles and their digits, are numerous rather irregular supporting rods, which have a tendency towards an elongated C-shape (Fig. 9). The surface of the body is very rough and prickly in all the specimens owing to the prominence of the projecting anchors. For this reason, I have selected the name for this new species, *Synapta acanthia.* (Plate IV.)

The exact relation of this synapta to previously known species is somewhat obscure. In the presence of two very distinct sorts of anchors, it approaches *innominata* and *bankensis*, two species described by Ludwig, from fragments from the other side of the globe. But the difference in the plates are so great, it is clear there can be no close resemblance to those forms. The new species will not fit into any of the five genera into which Östergen[4] has recently divided the genus *Synapta*, so that it must either be made the type of a new genus or else some one of his five genera will have to be modified for its reception. It approaches most nearly to *Synapta* s. str., from which it differs in the presence of two distinct sorts of anchors and plates and in the larger number of Polian vesicles, but the definition of the genus can be slightly modified to receive it and for the present it may remain there. It is certainly allied to *S. inhærens* which it superficially resembles quite closely.

In conclusion it seems desirable to add a revised list of the echinoderms of Bermuda with the important and, so far as possible, external and obvious, characteristics which distinguish each one. This is done to assist future students and visitors to the Bermudas to identify readily the species they collect and so to encourage such collecting. But it should be borne in mind that such brief descriptions are necessarily not exclusive, and will not distinguish closely allied species. Specimens not answering clearly to these definitions should be carefully preserved for further examination.

DESCRIPTIVE LIST OF BERMUDAN ECHINODERMA.

ASTEROIDEA. STARFISHES.

1. **Luidia clathrata** (Say).

Large flat starfishes with five arms (about five inches long), living on sandy bottoms or underneath the sand. Usually bluish-gray above and light beneath, but the only specimen recorded from Bermuda is said to have been " salmon-pink " when alive. Not at all common.

2. **Asterina folium** (Ltk.).

Small pentagonal starfish, less than an inch across, found on the underside of pieces of rock. Color varies considerably, usually light, often blue. Not very common.

3. **Linckia guildingii** (Gray).

Medium sized reddish- or yellowish-brown starfish with five or six rather slender, smooth, cylindrical or slightly flattened arms, from one to eight inches long. Found about the reefs but apparently quite rare.

4. **Asterias tenuispina** Lamk.

This starfish usually has six or seven arms, but the number varies from five to nine. They are nearly cylindrical, only slightly flattened, and very spiny. Color yellow or more or less orange with dark markings. Quite common.

OPHIUROIDEA. BRITTLE STARS.

1. **Ophiura appressa** Say.

Disc finely granular ; arm spines 8–9 very small ; arms cylindrical. Color brownish-gray, variegated with green, red and white ; arms banded with darker. Rather common, under rocks along sandy beaches.

2. **Ophiactis mülleri** Ltk.

Disc closely covered with radial shields and overlapping scales, the latter usually bearing small spines. Arms stout, somewhat flattened, bearing stout, smooth spines. Very small ; green and white. Rare.

3. **Ophionereis reticulata** (Say).

Disc covered with fine overlapping scales; in other respects like No. 6, but easily distinguished by the disc which is finely reticulated with dark lines. Very common, occurring in bunches in the sand and underneath rocks.

4. **Ophiostigma isacantha** (Say).

Disc coarsely granulated: arm spines 3, short and smooth; no tooth papillæ. Color whitish, the arms ringed with green. Rare.

5. **Ophiocoma echinata** (Lamk.).

This, the largest brittle star found in Bermuda, may be easily recognized by the very dark color and very spiny arms. The disc is an inch or more across and the arms are several inches long. Found under rocks on sandy shores but not very common.

6. **Ophiocoma pumila** Ltk.

Smaller than the preceding; disc granular, half an inch across. Arms long, slender and spiny. Arm spines 4–6. Color brownish-yellow, the arms banded with dark. The specimens before me from Bermuda all have six arms. Not common.

7. **Ophiomyxa flaccida** (Say).

Disc and arms covered with a thick naked skin; arm spines stout and thorny; large; color very variable, orange to olive green. Rare.

Echinoidea. SEA-URCHINS. SAND-DOLLARS.

1. **Cidaris tribuloides** (Lamk.).

This sea-urchin is seldom more than two inches in diameter, and may be very easily recognized by the stout, club-shaped spines. Common about the reefs off shore.

2. **Diadema setosum** Gray.

A large black sea-urchin with sharp, slender spines six inches long or more. Sometimes the spines are banded black and white. Common about the reefs off shore.

3. **Echinometra subangularis** (Leske).

This species is often called the "rock-boring" urchin as it is found in holes in the rocks about the reefs, where it is common. Color varies considerably, from reddish to black; the spines vary from light-brown, more or less greenish and tipped with violet, to almost black. The test is always oval or elliptical and somewhat flattened.

4. **Toxopneustes variegatus** (Lamk.).

A medium-sized almost spherical urchin, with numerous spines. The color varies greatly but Bermuda specimens are rich violet. Abundant.

5. **Hipponoë esculenta** (Leske).

A large, nearly spherical urchin with numerous short, white spines. Not common.

6. **Mellita sexforis** A. Ag.

This sand-dollar may be recognized at once by its extreme flatness and the six slits through the test. Color of Bermuda specimens, brown. Not common.

7. **Echinoneus semilunaris** (Gmel.).

This little elliptical spatangoid, seldom over an inch long, is easily recognized by the five equal, simple, narrow ambulacra extending from aboral pole to mouth. The spines are very short and light brown in color. In life the tube feet are bright red and stand out in striking contrast. Is found in the sand underneath rocks but has not been collected in Bermuda for some years.

8. **Brissus unicolor** (Kl.).

Oval spatangoid seldom over three inches long, of a grayish-brown color with numerous very short spines. Found in the same location with the preceding, and like it has not been recorded from Bermuda for some years.

HOLOTHURIOIDEA. SEA–CUCUMBERS.

1. **Cucumaria punctata** Ludw.

Small (two or three inches long), bluish- or yellowish-gray holothurian with ten branching tentacles. Found under rocks along shore. Not very abundant.

2. **Holothuria captiva** Ludw.

Rather small brown holothurian with twenty yellowish shield-shaped tentacles. Ventral surface somewhat flattened, with the numerous feet indistinctly arranged in three longitudinal series. Dorsal surface with rather numerous scattered papillæ, situated on small elevations. Not very common but occurs under broken slabs of rock with the following species.

3. **Holothuria surinamensis** Ludw.

Medium-sized holothurian, two to six inches long, of a generally brown color, blotched and spotted more or less indistinctly with darker: sometimes tinged with yellow. Tentacles shield-shaped, normally 20 (ranging from 10–21) yellow or whitish. Feet yellowish, not very numerous, scattered, not at all arranged in series. Dorsal papillæ not numerous, scattered, rather slender. Found under broken slabs of rock along shore. Quite common.

4. **Stichopus möbii** Semp.

Large holothurian, eight to eleven inches long, buff blotched with black. Tentacles shield-shaped, normally 20 but vary from 18–21. Feet arranged in three longitudinal series on the flat ventral surface. Rather uncommon; on sandy bottoms with the next species.

5. **Stichopus diaboli** Heil.

Large black holothurian, a foot long; the common holothurian of the Bermudas. Except for color, like the preceding with which it occurs though far more abundantly. *S. haytiensis* Semp. reported from Bermuda by Théel[5] is doubtless this form.

6. **Synapta acanthia,** NOV. SP. Plate IV.

Medium-sized synaptid, five or six inches long, white with a strong rosy tinge. Tentacles 12, each with 15–19 digits and 25 or more sensory cups on inner surface. No trace of eye spots. Anchors of two kinds, those of the rear of the animal long and prominent, giving a very spiny appearance and feeling to a contracted individual. Found in the sand in sheltered coves and probably not rare.

7. **Synapta inhærens** (O. F. MÜLL.).

Medium-sized synaptid, generally pure white, rarely rosy. Tentacles 12, with 7–11 digits each and about a dozen sensory cups on the inner surface. No trace of eye spots. Radial pieces of calcareous ring perforated for the passage of the nerve. Found in sand with the preceding but rather uncommon apparently.

8. **Synapta roseola** (VERR.).

Small synaptid, one to four inches long, bright rosy in color. Tentacles 12, each with 5–9 digits and 7–15 sensory cups. No eye spots. Radial pieces of calcareous ring simply notched, not perforated, for passage of the nerve. Found with the preceding but seems to be more common.

9. **Synapta vivipara** (OËRST.).

Small synaptid, reddish- or greenish-brown, generally more or less flecked with white. Tentacles 12 (11–13) each with 25–37 digits. No sensory cups but eye spots at base of tentacles. Body cavity usually contains young. Found in seaweed and under rocks, never buried in the sand. Apparently not common though recorded several times from Bermuda.

10. **Chiridota rotifera** (POURT.).

Small synaptid, one-half an inch to two inches long, white, yellowish or flesh-color. Tentacles twelve, each with 5–9 digits not arranged so pinnately as in *Synapta*. No anchors in the body-wall but wheels with six spokes. Body cavity sometimes contains young. Found under rocks in the sand, and in company with nos. 6, 7 and 8.

The list as above given includes all the echinoderms recorded from the Bermudas (except a few deep water forms) up to the present date. Although there are *five* additions to last year's list[1] there are *four* names of holothurians stricken off, so that there is only a net gain of one. Last year's list and the one above given compare as follows:

	1898.	1899.
Asteroidea.	3	4
Ophiuroidea.	7	7
Echinoidea.	8	8
Holothurioidea.		
Cucumaria.	2	1
Holothuria.	4	2
Stichopus.	3	2
Synapta.	1	4
Chiridota.	0	1
	28	29

Of course as this list is increased, as it doubtless will be, the above given "key" to the species will prove of less and less value but it is hoped it will be of some service to students and collectors for a few years at least.

AMHERST COLLEGE, 1899.

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PLATE IV.

PLATE IV.

ECHINODERMS FROM BERMUDA.

Synapta acanthia NOV. SP.

Fig. 1.—Anchor from posterior end of body. × 90.

Fig. 2.—Plate from posterior end of body. × 90.

Fig. 3.—Anchor from anterior end of body. × 90.

Fig. 4.—Plate from anterior end of body. × 90.

Fig. 5.—Abnormal anchor. × 90.

Fig. 6.—Twin anchors and plate. × 90.

Fig. 7.—Miliary granules from anterior end of body. × 450.

Fig. 8.—Miliary granules from posterior end of body. × 450.

Fig. 9.—Calcareous rods from the tentacles. × 450.

Fig. 10.—Radial and interradial pieces from the calcareous ring. × 10.

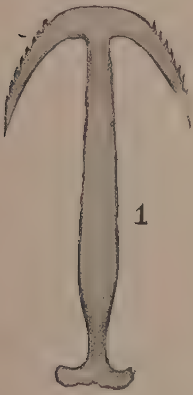
Fig. 11.—One of the ordinary ciliated funnels. × 90.

Fig. 12.—One of the large ciliated funnels. × 90.

Fig. 13.—Part of a large specimen, laid open along the mid-ventral line, to show the stomach, the straight course of the intestine, the large blood vessel and the row of ciliated funnels in the left dorsal interradius. Nat. size.

All figures were drawn with the aid of a camera except No. 13.

PLATE IV.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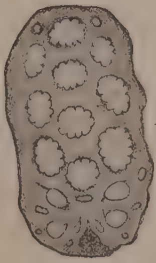
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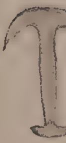
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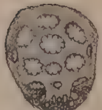
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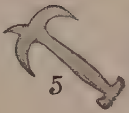
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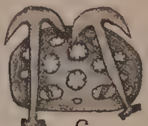
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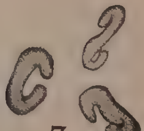
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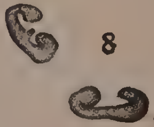
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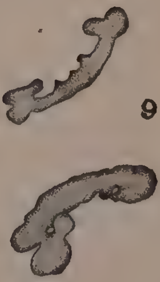
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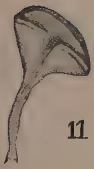
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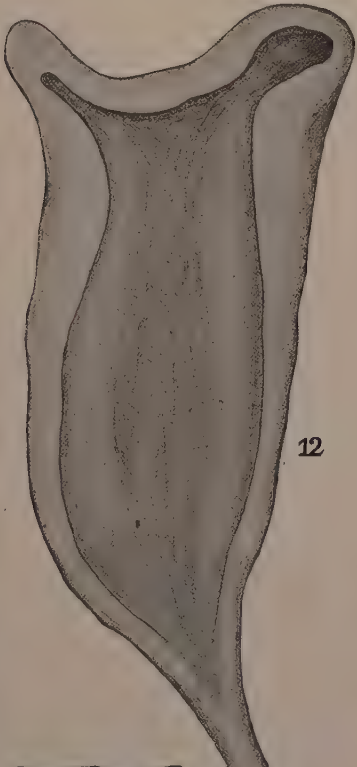
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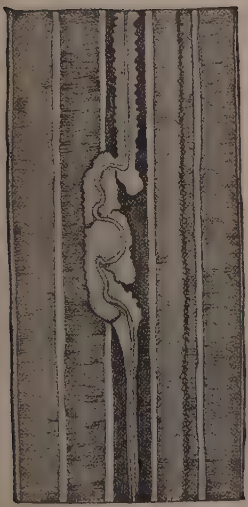
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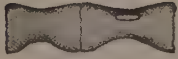
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[ANNALS N. Y. ACAD. SCI., Vol. XII, No. 8, pp. 187 to 340, Dec. 18, 1899.]

A CONTRIBUTION TO THE GEOLOGY OF THE NORTHERN BLACK HILLS.

JOHN DUER IRVING.

(Read March 20, 1898.)

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I. INTRODUCTION.

The Black Hills of South Dakota, as has been so well set forth by Newton in his classic work on the region and by many subsequent writers, constitute an elevated area, roughly elliptical in outline, situated on the western border of the state of South Dakota, but extending also into Wyoming. See Fig. 5.

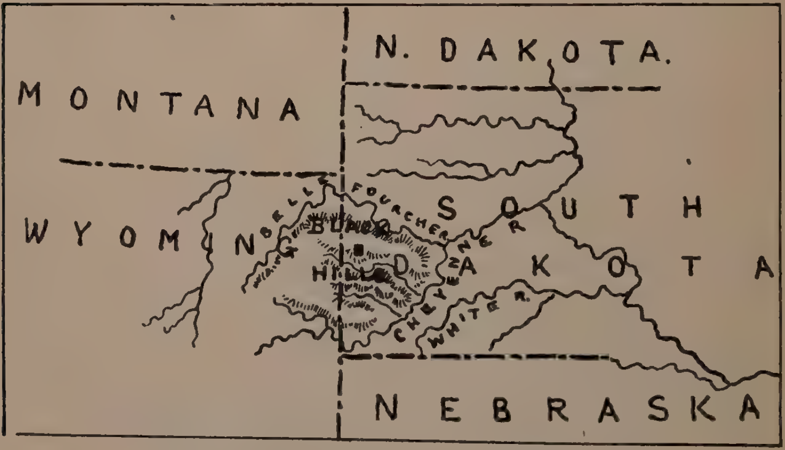

FIG. 5. Diagram to show location of Black Hills.

In the latter state and toward the northwest are the Bear Lodge mountains, the highest point of which is Warren's Peak. These constitute an uplift which is distinct both topographically and geologically from the Hills proper, and although the igneous rocks there exposed will probably prove to be genetically related to the eruptives of the northern hills, the district will not be included in this paper.

For a description of the general geological character of the hills we can scarcely do better than quote from Newton's introductory chapter :

"Around a nucleal area of metamorphic slates and schists containing masses of granite, the various members of the sedimentary series of rocks, the Potsdam, Carboniferous, Trias or Red Beds, Jura, Cretaceous and Tertiary lie in rudely concentric belts or zones of varying width, dipping on all sides away from the elevatory axis or region of the hills. From the hills outward the inclination of the beds gradually diminishes until all evidence of the elevation is lost in the usual rolling configuration of the plains. At numerous points also within the hills are centres of volcanic eruption." As Newton further goes on to describe, the Archean (Algonkian) area, which is some thirty miles in length by twenty-five in breadth, is situated very much nearer to the eastern than to the western border of the hills and forms fully one-half of the entire area. The nucleal area of schists and slates is not, however, as simple as would at first appear, for at some distance out in the western covering of sediments and between the main Algonkian nucleus and the western border of the ellipse is situated the additional uplift of Nigger Hill. We have here exposed an area of schists with associated granites just as in the Harney Peak region of the southern hills. Around the small Algonkian area is present the same Cambrian escarpment as that which characterizes the main nucleus. The Carboniferous rests upon it and dips away from the centre so as to quickly conform to the gradual slopes of the main ellipse. The uplift is of extremely local character and has exercised so small an influence on the general topography and drainage of the Carboniferous plateau, that, were the geologist to limit his observations to the periphery of the hills and to the more extensive Algonkian exposures to the east, he would have no suspicion of its existence.

Erosion has, however, exposed the same complex of eruptives as that seen in the more closely studied eastern regions, and it seems probable that we have here an important link of connection between the intruded masses of the northeastern portion of the Hills and the great eruptive center of the Bear Lodge mountains.

The area with which this paper is chiefly concerned is indicated by the black rectangle on the accompanying sketch map (Fig. 5) situated at the northern and narrower extremity of the main Algonkian ellipse. It embraces a portion of the older metamorphic rocks and that part of the Cambrian formation with which are associated the siliceous gold ores. A small area of Carboniferous limestone is included in the northeast corner dipping down below the later sediments of Centennial Park. On the west the area contains a large portion of the Carboniferous plateau which lies between the Algonkian of the main nucleus and the Nigger Hill uplift.

II. TOPOGRAPHY.

The topography of the district is intimately connected with the general geological character of the Black Hills. The drainage is toward the north and the east, the largest and most important stream being Spearfish creek. This stream follows a winding course with a general northerly trend and has carved for itself one of the deepest and most precipitous cañons in the hills. It crosses the district in the shape of a bow, in the southern arm of which it flows toward the northwest, and then with an easy bend takes a more northerly course. The latter is maintained until the river emerges from its deep cañon and enters the broad and open red valley which surrounds the hills. Into Spearfish creek, from the west flow Iron and Little Spearfish and many other streams, all having carved precipitous gorges from the massive, horizontal strata which constitute the flat, densely-wooded areas of the Carboniferous plateau.

In striking contrast to this table-land is the irregular topography presented by the eruptive region on the east of Spearfish cañon. In the immediate vicinity of the cañon itself are found the same narrow precipitous gorges between limestone walls, but as we pass toward the east we find that the country is composed of great numbers of irregular hills and ridges. Some of these are conical in shape, some are dome-like and others present sharp irregular crests, while between them all may be seen many smaller ridges and knolls which greatly complicate and confuse the drainage. A little to the south and east of the center of the district is Terry Peak 7070 feet in altitude, the highest point of the northern hills. To the northwest of Terry Peak, Elk Mountain and Ragged Top rise abruptly from the surrounding plateau, the former with a sharp, somewhat unsymmetrical contour, and the latter with a broad summit which curves out like a dome and meets the surrounding country in a low, rounded bluff. The two last named hills are much lower in elevation than Terry Peak and for that reason have been generally overlooked in the earlier descriptions of the region.

Directly east of Terry Peak is the sharp low-lying summit of Sugar Loaf hill from which there is a steep, precipitous descent on all sides. A little more than a mile and a half northeast of Terry Peak rises the beautifully rounded, dome-like mass of Bald Mountain, while immediately to the west and connected to it by a narrow ridge is the hill known as Green Mountain. To the north of Green and Bald Mountains are a group of exceedingly irregular, rounded and conical hills, massed together in a very intricate and confused manner. Of these the most prominent are War Eagle Hill, Richmond Hill and Ragged Butte.

The drainage of the district is divided into two distinct portions. In one the streams drain in a westerly and northerly direction into Spearfish creek ; in the other the waters find escape to the north through False-bottom creek, or in a direction more directly east into the valley of Whitewood creek. The division is made by a high ridge which passes through Deer Mountain, Terry Peak and Green Mountain, and thence runs almost directly north in an irregular line beyond the limits of the map.

The most important of the westerly draining streams is Squaw creek, which rises in the neighborhood of Green Mountain and Portland, flows northwest to and around War Eagle Hill, and then assumes a general northerly course. It finally sweeps sharply to the west and flows through a deep, rugged gorge with a general northwesterly trend to unite its waters with those of Spearfish creek in the extreme northwestern corner of the district. From the northwest it is fed by a series of almost parallel gulches, which are separated one from another by long rounded hog-backs; the latter often have quite precipitous sides and slope down abruptly at their extremities into the gorge of the main creek. The largest of these tributaries are Labrador gulch, the most easterly, and Redpath creek, the most westerly of the series. Both of them are long, rather deep gorges which enter Spearfish through narrow, almost precipitous gateways. Their sides and those of the cañon of Squaw creek reveal a very complicated geological structure which is the more difficult to unravel from the nearly inaccessible nature of the exposures.

Parallel to Squaw creek and something more than a mile to the south is a long, shallow stream known as Long Valley. It heads up at Crown hill, runs northwest, becomes a precipitous gorge below the town of Preston and enters Spearfish between high limestone bluffs. Around the north and south side of Ragged Top mountain run the the dry gulches of Jackass and Calamity creeks respectively, uniting just beyond the western extension of the mountain and opening into the Spearfish through the usual deep gorge. The two other gulches that drain the flat country between Elk mountain and Spearfish are Johnson creek and Elk cañon (McKinley creek), both with precipitous sides but containing no water throughout the larger portion of the year.

A little more than a mile south of Elk mountain is the deep gulch of Annie creek which flows into Spearfish almost directly from the east. As we follow the stream up its course two branches enter it. Ross Spring creek, its most northerly tributary, which heads up in the elevated region around Crown hill, has cut a deep ravine through the limestone into the underlying sediments of the Cambro-Silurian. Lost Camp creek, the most southerly with its numerous branches, rises in the broad amphitheatre on the western slopes of Terry Peak. Between these two streams are the waters of Annie creek itself, which heads up almost to the town of Portland, and is separated from the headwaters of Squaw creek by quite a narrow divide. Between this stream and Lost Camp creek rises the prominent rounded crest of Foley Mountain, which is connected with Terry Peak by a high semicircular divide, capped by a series of low dome-like knolls and enclosing a portion of the previously-mentioned amphitheatre.

To the south of Lost Camp creek, and separated from it by a low limestone ridge, are the two short, but precipitous gorges, which are occupied by Sweet Betsy creek, while still further to the south, and heading up into Terry Peak to the west of the Foley Flat amphitheatre, is the wild, deep ravine of Raspberry gulch.

If now we turn to the eastern slopes of the Terry Peak watershed, we are most forcibly impressed by the striking contrast between the two topographies. Instead of the narrow precipitous gorges with high, flat, table-like divides intervening, there is a great assemblage of irregular hills and divides of all shapes and sizes, and of so irregular a character as to completely baffle collective description. Nor is this contrast in any way confined to this district, but it will be noticed in every case where we pass from the Carboniferous plateau to the districts of Cambrian shale, with their vast confusion of dikes, sheets, and irregular intrusive bodies, a fact which emphasizes the inseparable connection between geological structure and the degrading forces of erosion.

On the southeastern slopes of Terry Peak and Deer Mountain the head waters of White-tail creek have their origin, and flow

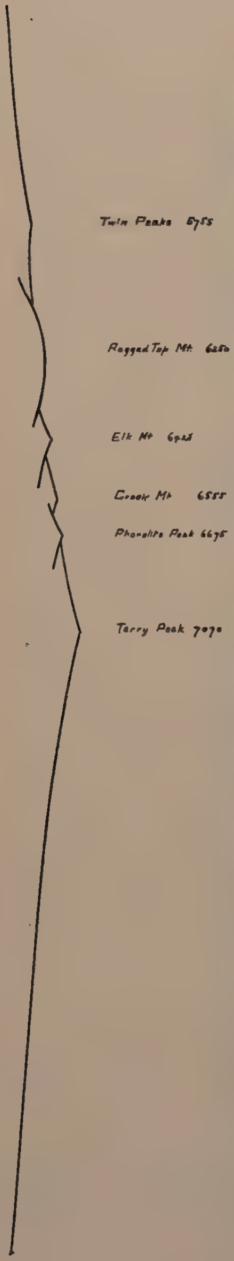

FIG. 6. Profile sky-line of Terry Peak and vicinity, as seen from "Cement Ridge," on the western side of Spearfish creek.

thence through a deep valley past the western and more precipitous side of Sugar Loaf hill. Into White-tail creek from the west empty a series of almost parallel gulches heading up on the eastern slope of Terry Peak and Green Mountain. The most important of these are Fantail gulch, which contains the town of Terry, and Nevada gulch, which forms a deep gorge just south of Bald Mountain, the two uniting before emptying into White-tail.

Still to the north of Bald Mountain are two important streams, False Bottom and Deadwood creek. Both head up near the town of Portland, the first to pursue a northerly course out to the plains of Centennial Park, but the second, with its many tributaries, to flow through a deep and often rugged ravine so as to unite with Whitewood creek at the city of Deadwood.

Probably the most notable topographic feature of the entire district is the predominant position of Terry Peak, from which the surrounding country gradually declines in every direction. Standing on the top of any of the high points on the western side of Spearfish creek one is very forcibly impressed by the prominent central position of this mountain.

The surrounding country rises gently from the more or less level ground to the south and increases its rate of elevation slightly, until, with a long, shallow sweeping curve, it culminates in the Sharp Crest of Terry's Peak. It then falls as gradually to the north, the various hill-tops seeming to arrange themselves one after another in the order of their elevation so as to scarcely interrupt the even contour of the declining country. (See Figure 6.)

III. STRATIGRAPHY.

It is not the purpose of this paper to enter into an extended discussion of the stratigraphy, but in order that the geological relations of the eruptive rocks and of the ore-bodies may be clearly understood, a brief exposition of the separate formations

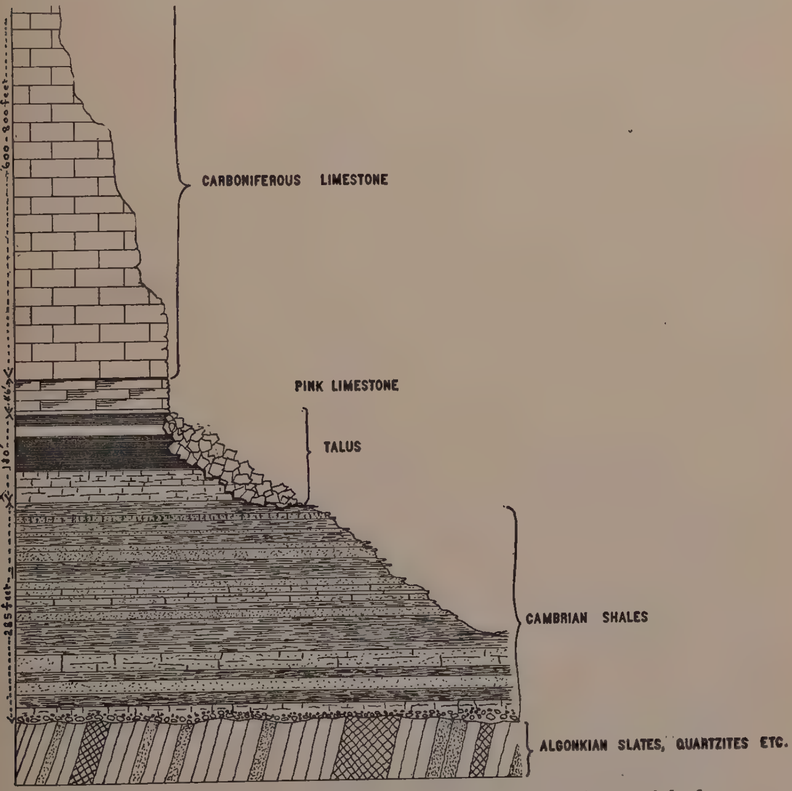

FIG. 7. Generalized section of the sedimentary rocks. Taken mainly from exposures near Elmore on the Burlington and Missouri River R. R.

and the problems that have arisen from their study is here introduced.

At the base of the stratigraphic column is a series of Algonkian slates, schists, quartzites and amphibolites; everywhere tilted at a high angle and showing an advanced state of metamorphism. Lying unconformably upon the eroded surface of the Algonkian is a series of calcareous sandstones, shales and limestone breccias which show a thickness of something over four hundred feet. In the localities where intruded sheets are numerous this thickness is greatly increased. Above these and lying in apparent conformity with them are the heavy-bedded limestones of the Carboniferous, which attain a thickness in the district mapped of upwards of 500 feet. Above this lies 125 feet of white and red, variegated, Minnelusa sandstones, of disputed age. They are generally regarded as Upper Carboniferous. This would then give to the massive strata of the Carboniferous age a total thickness of 625 feet. Certain shaly horizons exist in its limestone, but they are of minor importance, and as compared to the underlying Cambrian formation, the Carboniferous exhibits a very homogenous, heavy-bedded series. The Minnelusa sandstones are not exposed in the district mapped.

A. DESCRIPTIVE.

1. Algonkian.

The rocks of the Algonkian which are exposed in this area are garnetiferous mica schists; micaceous slates, which grade into extremely fine phyllites; argillaceous slates; finely bedded and greatly indurated quartzites or quartz-schists; and finally amphibolites and hornblende schists of endless variety. The series is exposed in the vicinity of Central City, Texana and White-tail gulch. It passes beneath the overlying Cambrian on the west and south before we arrive at the towns of Portland and Terry. To the north and east it disappears in the vicinity of Sheeptail gulch and Garden City. The Algonkian exposure extends as a long tongue up into White-tail gulch before it is buried by the palæozoics and outcrops appear likewise in Fantail and Nevada gulches. On the narrow divides, between the gulches, are found the basal quartzites of the Cambrian. The slates appear again still farther up Nevada gulch in a large exposure and have evidently been raised to a higher elevation by a fault whose down-throw is toward the mouth of the gulch. Thence the line of contact passes around the northeastern slopes of Bald mountain and across the headwaters of Deadwood gulch. It then bends out to the west of a large quartz porphyry mass into the head of East Squaw creek. Thence it crosses the divide to the west of this stream into the valley of Squaw creek itself. The exposure in the bed of this stream is a dense, fine-grained, greenish amphibolite which extends far toward the northwest and eventually disappears beneath the westwardly dipping Cambrian quartzite. Other exposures of amphibolite occur in the form of dikes, which are conformable to the slates and are present all along White-tail gulch. The garnetiferous schists are best exposed below Central City, in Deadwood gulch. The dip of the schistosity of the Algonkian is nearly vertical throughout, but such inclination as may be detected in a large number of observations, seems to be to the east.

The term Algonkian is substituted for Archean because, with the exception of the amphibolites, the series is of undoubted sedimentary origin. That the statement is true is shown by the development of slaty cleavage at an angle to the original bedding. These relations are very marked in many localities. A photograph of slate taken from the De Smet cut will be seen in Plate VII. As further proof Professor Crosby[1] has mentioned metamorphic conglomerates which occur near Galena and Professor Van Hise has still further mentioned slaty cleavage cutting the original sedimentary banding. There is then no question that the slate series originally consisted of mechanical sediments which have attained their present crystalline condition through the agency of metamorphism. Whether the schists will likewise prove to be referable to the Algonkian is, as yet doubtful. It will depend upon the validity of the two-fold grouping of the series. Newton divided it into a newer or Eastern series of slates and an older or Western series of schists, which he correlated with the Huronian and Laurentian respectively. Carpenter and Crosby have sustained this division, but the latter authority correlated the rocks with the Archean of New England.

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[1] Proceedings of the Boston Society of Natural History, XXIII, 494 1888.

Van Hise[1] studied the district in 1889 and stated it as his belief that no division into two unconformable series could be established. He attributes the more thoroughly crystalline character of the schists of the Western series to the metamorphic action of the intruded granite. He then mentions an area of garnetiferous schists about Deadwood and shows that the slates there pass insensibly into schists. The intruded rocks of the northern hills he considers as the agents that have metapoosed portions of the slate area into crystalline schists. Although the writer has not seen the schists of the southern hills, he has examined carefully the schistose area between Deadwood and Central City and cannot agree with Van Hise that these schists are the result of contact metamorphism. The slates do unqestionably grade into schists as we descend Deadwood gulch beyond Central City, but it is especially in these schists that dikes are noticeably rare. On the other hand in those portions of the Algonkian area, such as the region around Texana, and in the vicinity of Terry, where the eruptives are in enormous development, the Algonkian rocks are preëminently argillaceous slates and phyllites. These schistose areas must then be attributed to the locally greater strength of the same metamorphic agencies that have altered the entire Algonkian series, rather than to the influence of intrusives.

2. Cambro-Silurian.

A complete section of rocks forming the Cambrian was not obtained at any one locality. In the cañon of Spearfish creek the lower strata were found quite well exposed, but the upper

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[1] C. R. Van Hise, The Pre-Cambrian Rocks of the Black Hills. *Bull. Geol. Soc. of America*, I, 203, 1890.

STRATIGRAPHIC SECTION.

	Section at Elmore. Bed.	Feet.	Section from Crown Hill, Portland, and Mine Shafts.
Sub-Carboniferous.	1. Directly underlying the Carboniferous is a pinkish, very evenly bedded limestone. It is quite massive, contains no fossils and is extremely soft. Seams of a white, hard, cherty material run through it parallel to the lamination, and are often quite persistent. They sometimes attain a thickness of 6 inches.	40	
	2. Compact purplish to white and lilac-colored limestone, quite pure and highly fossiliferous. Contains crinoids and *Productus*.	6	
			Crown Hill.
Silurian.	←130 feet.→ Talus of large limestone blocks which have fallen from above.	20+	Sandy limestone of a yellowish color containing *Maclurea magna*, and many large *Orthoceratites*, *Halysites catenularis* and other unidentified fossils. Thickness undetermined.
		75+	Fine slate-colored limey shales breaking into exceedingly minute fragments of great thinness.
Cambrian.		20+	Scolithus sandstonee heavy-bedded and of indefinite thickness. Forms top of the unquestioned Cambrian. Contains borings of *Scolithus linearis*, but these may be absent. Locally known as the "worm-eaten" or "upper" quartzite or as the "upper contact."
		15	Reddish shales and shaly sandstones.
	Alternating shales and shaly sandstones of varying thickness often glauconitic and prevailingly reddish or yellowish from oxide of iron. Limestone conglomerates or breccias termed interformational conglomerates also occur, but are not confined to any one horizon and are not persistant features.	250	
			Mine Sections at Rua, Union, Big Bonanza, etc.
		18+	Reddish, sandy, crystalline limestone locally known as "sandrock." It is exceedingly calcareous, and when unoxidized forms hard, compact, bluish material which is termed blue "sandrock," but is in reality a crystalline limestone.
		20	Hard quartzitic conglomerate coarser at the base and lying unconformably on the Algonkian series.
		464	

portions of the formation to a distance of 130 feet below the pinkish limestone were so generally covered by a heavy talus of limestone, that they could not be seen. In other localities they are exposed, but are so broken and disturbed by intrusions of igneous rocks, that their exact thickness and sequence could not be accurately determined. In the diagrammatic section, Fig. 7, the lower portion was taken from the exposure on the north bank of main Spearfish Creek, just beyond Elmore, and is quite correct; the upper 130 feet is from exposures at Crown Hill and Portland, and is of questionable accuracy. A section of the formation, which has been compiled from the various localities is given on p. 199. This section will give an approximate idea of the character of the Cambrian formation in this region. The Silurian shales and limestone are quite persistent in their occurrence, but all of the alternating series below them show great local variations. The exception is the quartzitic conglomerates at the base, which is everywhere present. No attempt has been made on the map to differentiate the formations lying below the Carboniferous, as they are difficult to separate accurately in so disturbed a district. All between the Algonkian and Carboniferous, have been classed as Cambro-Silurian.

The Cambrian strata are exposed in the vicinity of Terry Peak and Portland, and in Ruby basin, which lies to the east of Terry Peak. They are too much disturbed by intrusion to afford very reliable evidence as to dip, but the general trend is toward the west. (Plate VIII.)

The streams of Spearfish, Squaw, Raspberry and Annie creeks, have cut through the overlying Carboniferous strata, and have exposed the Cambro-Silurian beds below. In these exposures the determination of dip is somewhat more reliable. In Raspberry gulch near the forks, the dip is ten degrees west of south, but it shifts gradually around toward the west and finally at the mouth of the gulch, the strata are perfectly horizontal. As we descend Spearfish creek, however, we approach the northern slope of the Black Hills uplift and the dip swings gradually around toward the north, and eventually brings the Carboniferous across the stream bed.

In general little can be added to the work of Newton as regards the Cambrian. There are, however, several points deserving of special mention. The first is that the Cambro-Silurian formation as a whole is one which, from its thinly bedded character, and the easily cleavable nature of its component sediments, has afforded an extremely easy access both to the intrusion of igneous rocks, and to the passage of ore-bearing solutions; the second is that the high percentage of carbonate of lime, which characterizes most of its shales and sandstones, has rendered them very susceptible to replacement and thus enabled siliceous solutions to deposit their burden of silver and gold.

3. Carboniferous.

The Carboniferous formation is represented in this district by a series of very heavily bedded gray limestones, which attain a considerable thickness to the west of Spearfish creek. They dip with the underlying Cambro-Silurian strata in a westerly direction and gradually become thicker as we pass from the eastern border of the exposure, until in Spearfish cañon they attain a thickness of over 500 feet.

No careful section of this formation was made, but the important features of the series are its great thickness and its massive, homogeneous character. The latter has made it an extremely resistant rock, both to the intrusions of igneous magmas and to the passage of ore-bearing solutions. Shaly horizons occur only at rare intervals, and then are separated by considerable thicknesses of more massive strata.

The relation of the Carboniferous formation to the topography has already been touched upon. The character of rock is responsible for the deeply carved and precipitous nature of the gulches. The streams which have penetrated the limestone have found the underlying shales of the Silurian formation an exceedingly soft and easily eroded series, and have cut them from beneath the heavy limestone above, causing the latter to break off in huge blocks, that have left behind great perpendicular cliffs and have strewn the bottom of the gulches with a rugged and irregular talus. Indeed one would scarcely realize, in studying the eastern portion of the hills, that in an uplift of such slight comparative elevation, erosion could have cut into the uplifted strata so bold and steep a cañon as that of Spearfish creek. Another very noteworthy feature of the gulches in the limestone is that they are in the majority of cases without water for the greater portion of the year. Those which have cut through into the Cambro-Silurian contain water, but the others do not. This seems to have been the result of the solubility of the limestone, which on the west of Spearfish shows many sinkholes, some of which are of no inconsiderable size. The stream of Beaver creek is particularly noticeable in this way, for it flows for some distance as a good sized creek, and then sinks beneath the limestone, to appear again after a subterranean passage of some miles.

That faults of considerable magnitude have occurred in the limestone, in connection with the uplifts of Ragged Top, and the eruptive masses of Squaw creek seems probable. They are suggested by the presence of frequent brecciated zones, which have afforded crevices, through which subsequently stimulated, siliceous solutions have made their way, transforming the broken limestone into a hard flintlike mass of cemented fragments. The Ragged Top verticals are of this type.

B. HYPOTHESES REGARDING HISTORY OF REGION.

The geological history of the Black Hills uplift has been discussed at some length by Newton,[1] and subsequently by Crosby[2] and Carpenter.[3] The hills were probably an island during the period following the metamorphism of the Algonkian series, and upon the shores of this gradually sinking land were deposited the materials derived from its degradation. Thus was formed first the coarse, basal conglomerate, which everywhere lies at the base of the Cambrian formation. That this island was never entirely beneath the waters has been proved by Crosby,[1] who shows that the Cambrian series sinks to a thickness of barely 50 feet in the southern hills, and there dips away from the central, granitic area at too slight an angle to have extended up over the higher peaks. Following the deposition of the Cambrian there is a great, unrecorded, geological interval during which the Ordovician, Silurian and Devonian strata were deposited in other parts of the continent. Since the studies of Newton, strata of probable Silurian age have been identified and we have a partial filling of the gap. The absence of Devonian strata is, however, still to be explained. If present, these must have but a slight development, because there is only a short space between the Silurian and those rocks which are of positive Carboniferous age.

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[1] The Geology and Mineral Resources of the Black Hills of Dakota, pp. 203–224.

[2] Proc. Bost. Soc. Nat. Hist., Vol. XXIII, page 488.

[3] Preliminary report of State School of Mines of South Dakota. Pages 11–52.

For this break two explanations have been advanced:

1st. That the Black Hills area was elevated at the close of the Cambrian, so as to be covered by a very shallow sea. During this time little or no sedimentation occurred, nor was there any marked erosion. Subsequently a gradual subsidence took place and the Carboniferous series was deposited with perfect apparent conformity. Against this may be advanced the argument that no conglomerates exist at the top of the Cambrian to indicate shore conditions. If, however, the area of the hills formed the bottom of a shallow sea, without itself projecting above the surface, the absence of conglomerates presents no difficulties. Other land areas were too remote to have supplied them.

2d. The other view is that the absence of these formations indicates the subsidence of the region of the hills to abyssmal depths, during which time little or no sedimentation occurred, and that the deep-sea deposits, such as have been shown to accumulate with extreme slowness in all known localities, are so thin that they have not yet been identified. If this view be accepted it is necessary to suppose the occurrence of a very sudden subsidence of the entire area to vast depths, for the Cambrian series is throughout a deposit characteristic of comparatively shallow seas, and no series of limestones exists between it and the strata in question to indicate a gradual sinking. Such a profound and sudden subsidence could hardly have occurred without a disturbance essentially cataclysmic, and to the writer's knowledge no evidence of such a disturbance is at hand.

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[1] Proceedings of Boston Society of Natural History, Vol. XXIII, 507.

The writer would then incline to the first explanation and attribute the absence of the Devonian partially to that explanation, and partially to the belief that the missing series may be represented by still unidentified strata. Furthermore, breaks may exist, which are as yet undetected, because unconformities which might be produced in shallow seas of this description are not marked, and are difficult of recognition. Close study, such as is necessary to establish their absence, has not yet been put upon the subject. Investigations are now in progress by the United States Geological Survey, and will probably throw light on this much mooted question.

Subsequent to the Cambrian, a gradual subsidence seems to have occurred, during which the Carboniferous strata were laid down, and following their deposition a gradual elevation began which seems to be still in progress at the present day.

IV. ERUPTIVE ROCKS.

I. STRUCTURAL AND DYNAMIC RELATIONS OF ERUPTIVE ROCKS.

A. DESCRIPTIVE.

The eruptive rocks present in their structural relations three easily separable and distinct groups, which are found respectively in the three great stratigraphic formations of the hills. They are therefore discussed under the following subdivisions:

a. Intrusions in the Algonkian.
b. Intrusions in the Cambro-Silurian.
c. Intrusions in the Carboniferous.

a. Intrusions in the Algonkian.

Of the intrusions in the Algonkian formation we have but a single type—dikes. These may be subdivided into two distinct varieties: pre-Cambrian dikes of amphibolite and hornblendic schist; dikes of phonolite, quartz-porphyry, etc., of early Tertiary time.

The two are widely separated in age and petrographic character. The former were intruded before the metamorphism of the slates and schists, and shared in their alteration; the latter came in long after those rocks had assumed a vertical position, and had received their covering of sediments. The later eruptives are, therefore, to be regarded as true dikes, while the earlier basic intrusions are, despite their similar structural relations, really intruded sheets. As both usually conform to the bedding of the Algonkian rocks, and are now in a vertical position, we shall class them together as dikes, and defer until later the discussion of their petrographic and genetic differences.

The dikes of later intrusives are scattered in great profusion over the entire area of the Algonkian. They may be observed making long prominent hills, with a general northwest and southeast trend, from the sides of which the softer and more easily eroded schists and slates have been worn away. In Deadwood gulch their great numbers may be perhaps better appreciated than in any other part of the area. On Dead Dog hill are four large and distinct dikes striking northwest and southeast, parallel to the strike of the slates. Just above Texana is an exceedingly prominent one, which forms a long ridge on both sides of Deadwood gulch, and which can be traced for nearly half a mile in either direction. As we pass on along the Fremont, Elkhorn and Missouri Valley R. R. between Texana and the large dike to the west of Go-to-hell gulch, a distance of hardly one mile, no less than twenty-two dikes of from ten to 100 feet in width jut out from the bank along the northern side of the railroad. Between these lie intervening portions of schist and quartzite; dikes of amphibolite and hornblend schist; and innumerable smaller dikes of porphyritic rock. The latter are of such small size that it has been impossible to map them. At the point where a large stream branches off to the south extending up into the Algonkian heights beyond Deadwood gulch, the track enters a deep gorge, which the waters of Deadwood gulch have cut in a huge dike of tonalite. This dike continues to form the walls of the gulch until we have almost reached the mouth of Go-to-hell gulch. It is nearly fifteen hundred feet in thickness and, from its great size, is somewhat more unconformable to the slates than the smaller dikes. Beyond this the dikes are seen only at rare intervals, and from Central City, where the Algonkian grades imperceptibly from slates and phyllites into garnetiferous schists, to Deadwood, only an occasional dike is to be seen. If, now, one ascends the northern side of the gulch west of Central City, and walks thence westward along the divide between Deadwood and Sheeptail gulches, a new feature in the relations of the intrusions will become manifest. Instead of the separate and distinct dikes, that appeared in the slates along the railroad, the entire divide is made up of irregular bosses of porphyries, phonolites, and intrusives of all descriptions, mingled together in inextricable confusion, Occasionally fragments of Cambrian quartzite and conglomerate may be seen in the porphyry. Residual fragments of this basal conglomerate may also be now and then observed lying on the upturned slates, where some higher point of a former Algonkian surface protrudes through the capping porphyry. It seems probable that we have here the lowest horizon of horizontal intrusion. In other words, the porphyry, which occurs in dikes in the slates below, on reaching the hard basal quartzite found the lines of least resistance in a horizontal direction, and lifted the resisting, superincumbent mass so as to spread out on the irregular surface of the Algonkian below. Dikes of phonolite seem to penetrate the older and more decomposed bosses

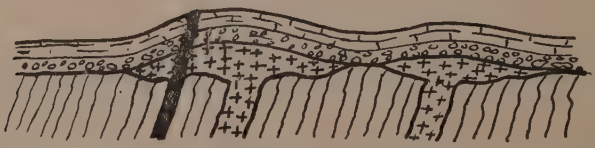

Fig. 8. Diagrammatic section of divide to the north of Deadwood gulch to illustrate nature of porphyry masses beneath the basal Cambrian conglomerate.

of quartz-porphyry, although specimens of the actual contacts could not be obtained. Fig. 8 illustrates the character of these intrusions.

Continuing up on this divide we leave the porphyry hills and again cross the Algonkian with its innumerable numbers of intruded dikes. To the north of this divide, in the direction of Garden City, the entire area of Algonkian slate is one maze of parallel dikes and conical porphyry hills, the former appearing most frequently when the slates are cut below the level of the deposition of the Cambrian, and the latter when the erosion has done no more than remove the basal series and expose the porphyry below.

These conical caps to Algonkian hills have led Dr. Jenney[1] to suppose that erosion had removed the Cambrian from the surface of the Algonkian previous to the intrusion of the igneous rocks. This would, however, necessitate the existence of superficial characters in the rocks. Such are invariably absent, and the rocks are of typical, intrusive character.

Besides the dikes in the gulch of Deadwood creek a great number may be observed in Whitetail gulch, near Sugar Loaf hill. Between that mountain and Lead City, along the Black Hills and Fort Pierre Railroad, a great many dikes have been exposed on the hill-side, and jut out into the gulch below the track. They are of phonolite, quartz-porphyry, etc., together with amphibolites of very diverse textures.

Innumerable dikes intersect the Algonkian in the mouth of Fantail and Nevada gulches. All of these form prominent ridges, but must be distinguished from the ridges of quartzite which are always seen in the schist areas, and by reason of their indurated character often attain greater prominence than the dikes themselves.

The dikes in the Algonkian are sometimes of very great size. A mass of this character occurs a short distance west of Central City in Deadwood gulch. Another is the large outcrop of phonolite in False Bottom creek. A third is the very large dike of rock related to dacite, which is exposed on the Fremont,

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[1] *Black Hills Mining Review*, March 21, 1898, Vol. X., p. 10.

Elkhorn and Missouri Valley Railroad, at the apex of the easterly pointing loop between Texana and Bald Mountain. Of these the phonolite in False Bottom creek is the most conspicuous. It is a very coarse, trachytoid variety, and is mingled with masses of a more fine-grained character. The mass is best exposed about 300 feet north of the junction between the False Bottom and Carbonate roads. As one stands on the summit of War Eagle hill, and looks north, this mass can be seen to cover a great area, and may be easily distinguished from the other intrusions and dark mica slates, by the whitish decomposition product that coats its exposed surfaces. The contact with the slates is not very regular, as it sometimes cuts athwart them and presents a quite uncomformable boundary.

In the bed of Squaw creek at the mouth of Labrador gulch and thence on down the stream, a great irregular mass of amphibolite is exposed. This is unconformably covered by the Cambrian, and is extremely interesting, in that it shows that the older basic eruptives intruded in the Pre-Cambrian sediments, were at times exceedingly irregular, and of great extent. For the most part they seem to have been intruded sheets, which have since been turned on end and buried by the Cambrian; but this Squaw creek mass as well as other gabbroic amphibolites between Deadwood and Custer Peak, and many others in the northern hills, would seem to point to the existence of large intruded laccolitic masses of pre-Cambrian age. One cannot fail to be impressed with the extent of these metamorphosed eruptives, for they show that the hills were the seat of a period of prolonged and widespread igneous activity, long before the deposition of the Cambrian.

Such dikes of the later eruptives as occur in these amphibolite areas, do not, of course, preserve the regularity of strike which characterizes those in the slates; for in general there is no cleavage in the massive rocks to determine their direction.

The dikes in the Algonkian occur in such great profusion that it has been impossible in one season to trace out even the larger ones. The have not therefore been indicated on the map except along the course of Deadwood gulch, and a few in the neighborhood of Sugar Loaf hill. But were the whole of the Algonkian area carefully mapped, it is no exaggeration to say that at least one-third if not more, would be igneous rock. Some idea of this may be obtained from the map if we conceive the dikes on Deadwood gulch to be produced in either direction to the limits of the slate exposures, and the space between them seamed with dikes too small to map.

b. Intrusions in the Cambrian.

1. LACCOLITES.

Of the bewildering series of igneous intrusions that intersect the Cambrian formation the most conspicuous, and without doubt the most important and interesting, are the laccolitic peaks. As compared with those of the Henry mountains, as well as those described by Whitman Cross from Colorado, they are of a much smaller size, a fact which has made their study a matter of comparative simplicity. Within the area mapped are no less than six igneous masses of a distinct laccolitic character, in addition to which are described two laccolites from the vicinity of Nigger hill to the west of Spearfish creek. With the exception of Crow Peak, of which the writer has made only a cursory examination, the two most perfect laccolitic masses are Sugar Loaf hill and Ragged Top mountain, and these will for this reason be given the precedence in description.

Sugar Loaf Hill Laccolite.

Sugar Loaf hill is situated just to the east of Whitetail gulch, almost directly opposite to the mouth of Stewart gulch. It forms a sharp peak, which, when compared with Terry Peak and the general level of the surrounding country, attains only an insignificant elevation (6,030 feet). The waters of Whitetail creek have carved around its western and northern sides a deep gorge, from which the mountain rises in an abrupt, almost precipitous cliff to the height of 550 feet. On the east and south from the summit is a steep fall of 100 feet, to the comparatively level table-land below. On the northeast of the hill is a short and quite deep gulch draining to the northwest and uniting with Whitetail gulch just below the horseshoe loop of the Black Hills and Fort Pierre R. R.

The general shape of the hill is that of a rather flat cone, with a sharp crest, steep on the north and west, but buried in sediments, both east and south. As laccolites go, it is extremely small, scarcely attaining a maximum diameter of three-quarters of a mile.

On the west side of Whitetail gulch the country falls gently from the rather flat region south of the town of Terry, but is interrupted some 50 feet from the bottom of the gulch by low walls of phonolite, which have an irregular castellated scarp and slightly increase the steepness of the descent into the bed of the stream. This same slope is broken by the incision of two quite prominent, parallel gulches, through the most southerly of which passes a spur of the Deadwood Central R. R., entering Whitetail just below the "Ruby Bell" mine and Stewart gulch, slightly north.

Geologically, Sugar Loaf hill is situated on the northern border of the Cambrian escarpment. To the north is the broad expanse of Algonkian slate, a long tongue of which formation runs up the bed of Whitetail to the mouth of Stewart gulch. Above this, and lying horizontally, are some 40 to 50 feet of Cambrian quartzite and shales; over this in turn is the phonolite of Sugar Loaf. The lower contact is best seen in the two westwardly-heading gulches, and at a point a short distance below the Union mine. If we now ascend the bed of Whitetail, the blocky columnar phonolite may be observed on both sides of the gulch, extending uninterruptedly upward on the east and north to the crest of the peak but passing on the opposite side beneath the overlying shales. The latter run out for some distance on the tops of the little divides. Still further and near the Union shaft the shales overlie the phonolite on both sides of the stream, and the stream bed itself passes up into that rock eight or nine hundred feet north of the bend in the B. & M. R. R. From the east and south sides of the mountain the sediments have not been removed, so that the phonolite is not exposed, until we have approached much nearer to the top of the steeper portion of the hill. It has been difficult to obtain data as to the dip of the overlying shales, for these are covered to the east and south by a residual talus of the white, almost aphanitic rhyolite, so extensively developed about the town of Englewood. Even where they have been uncovered by the innumerable prospect holes that dot the region, they have been of so fine and easily contorted a character as to furnish no reliable information. It is probable, however, were a series of observations available, as may at once be seen from the section, that the low flat nature of the laccolite would render the establishment of a distinct quaquaversal a matter of no little difficulty.

Still, in view of the fact that the semicircular incision made by Whitetail gulch has cut almost through the heart of the mountain and exposed both its lower and upper contacts, little better proof of its laccolitic character could be desired.

The symmetry of the intrusion is marred on the northern side by a large dike of an extremely coarse quartz porphyry. This, together with numerous other northwest-southeast-striking dikes, has formed an effectual barrier to the further extension of the intrusion in this direction. The rock itself is a dove-colored phonolite of the trachytoid type. As one ascends the hill from the Union mine, the rock can be seen standing in large, roughly hexagonal columns, which possess the characteristic platy cleavage of phonolite in such perfect development as to almost resemble a sedimentary rock, The accompanying photograph (Plate VIII.), which was taken about half way between the summit of the mountain and the bottom of the gulch, will illustrate this. The plates are readily separated one from another, and seem to be due partially to strains developed in cooling and partially to weathering. They give out the clear ringing sound from which phonolite has derived its name, and seem to be but little decomposed.

Considered as a whole, Sugar Loaf hill may be regarded as a rather more perfect specimen of laccolitic intrusion than we are accustomed to expect in a region so seamed with intrusives. It is true that on the northern side of the mountain the phonolite seems to cease almost abruptly, being complicated by the quartz-porphyry, and observations in the Union Mine also show that dikes and sheets of phonolite ramify in all directions through the shales that lie between it and the Algonkian, and prove that the lower contact of the phonolite is not nearly so regular as the exposures in Whitetail and Stewart gulches would lead one to believe.

Contact metamorphism does not seem to be common either in the shales above or below the mass. Silicification, it is true, has been quite widespread, but is to be sharply distinguished from contact metamorphism. It is to be attributed to the effect of solutions rendered more active by the intrusion, and not necessarily contemporaneous with it, rather than to the baking effects of the heated magma.

In closing this brief description perhaps the most striking features of the intrusion are its circumscribed character, for it may be readily studied in a day, and the singularly fortunate way in which a rather advanced erosion has revealed its laccolitic nature.

Ragged Top Laccolite.

A little to the north of west, and about one mile distant from Crown hill, the low dome-like mass of Ragged Top mountain rises some four hundred feet above the level table-land of the Carboniferous plateau. It lies between the two confluent gulches of Calamity and Jackass creeks, the former shallow along the upper part of its course, but becoming precipitous as it rounds the western end of the mountain. Here it unites with the more deeply carved gulch of Jackass creek. Thence the two pass together between almost perpendicular walls of limestone into Spearfish cañon. As seen from the top of Crown hill (see Plate IX.), it is a long, low, oval dome of a very regular aspect, and the same outline appears when it is viewed from Dacy Flat to the north. It is only when one ascends the mountain itself that the extremely rough and irregular character of the hill can be fully appreciated. In going upward from the west, north or east, one passes over gently sloping strata of Carboniferous limestone, which have an increasingly steep dip, until within two hundred and fifty feet of the summit. A rounded bluff of phonolite is then encountered, over whose crest one may readily climb, and proceed up a decreasingly steep rise to the flat top of the hill. From this point the mass presents a somewhat unique topographic appearance, for it comprises two almost distinct, roughly triangular masses of phonolite. The broader and flatter of the two lies to the east and is connected with the more precipitous western mass by a narrow and almost dike-like ridge of the same rock. From both of these masses incurving tongues of phonolite run out to the south circling toward one another, so as to include and almost surround a large southwardly inclined amphitheatre. The more westerly of the two is the more pronounced.

The most conspicuous feature of this enclosure is that its interior boundary is exceedingly precipitous, and that the inner cliff, notably at the western end, extends around so far as to run in a direction almost parallel to itself. It is broken away at the center, and thus affords egress to springs that rise amongst the the thick forest of Jack pines, which grow from the great mass of sloping talus, and débris within. The steepness is not confined to the interior of the basin, for the western arm forms, on the outside, an exceedingly abrupt bluff, which rises almost two hundred and fifty feet from the bed of Calamity gulch. The great rough irregular columns of phonolite stand out sharply in picturesque and rugged beauty against the sky. (See Plate X.)

Plate XI., from a photograph taken from the top of Elk mountain to the southeast, will give an excellent idea of the crater-like depression and the peripheral valley which surrounds the hill on the south and east.

If one now crosses Calamity creek to the top of the limestone bench, at a point a little to the east of the Metallic Streak mine, the slight, almost imperceptible westward dip of the limestone may be seen to greatly increase as the phonolite is approached, until at the foot of the bluff, or about twenty feet distant therefrom, it has attained an angle of fifty-one degrees. This will be brought out quite distinctly by the accompanying photograph, and the diagram which has been traced from it, plate 9. Passing now up the bed of Calamity creek one finds the talus covering everything on the northern side of of the gulch. On the south side, however, the escarpment of limestone can be seen capping the divide and below it in numerous prospect holes the miners have opened the Cambrian shales, or, more properly speaking, those of the Silurian, which immediately underlie the limestone. These shales become more extensively exposed as we approach the slopes of Elk mountain, and are to be found far up on the northern slopes of the hill, but the geological relations in this direction have been complicated by the Elk mountain upheaval. It is, therefore, difficult to say how much the extent of this Cambrian exposure is due to that intrusion and how much to Ragged Top. From Elk mountain towards the north extends a quite prominent ridge of limestone. In the low valley between this and the slopes of Ragged Top is the town of Balmoral. No outcrops of shales can be found in this valley, for even the prospect holes have not penetrated the thickly strewn talus. The Cambrian formation is not visible at any other point around the mountain, but an artificial exposure has been made available on the northern slopes of the hill by the Badger shaft.

The Badger shaft is situated on the north side of the mountain, just to the east of a small draw running into Jackass creek, and not more than sixty feet from the phonolite bluff. It has now reached a total depth of three hundred and sixty feet. For three hundred and sixteen feet the shaft penetrated the Cambrian formation, and at that depth entered phonolite dipping a little to the west of north, at an angle of about forty-five feet. The phonolite is identical in every way with that exposed on the top of the mountain. At the depth of one hundred and five feet a drift was run toward the south and the phonolite encountered at a distance of eighteen feet, the shales lying against it in an almost vertical position. Another drift was run in the opposite direction at the three hundred and twenty-five foot level, and the overlying shales penetrated at a

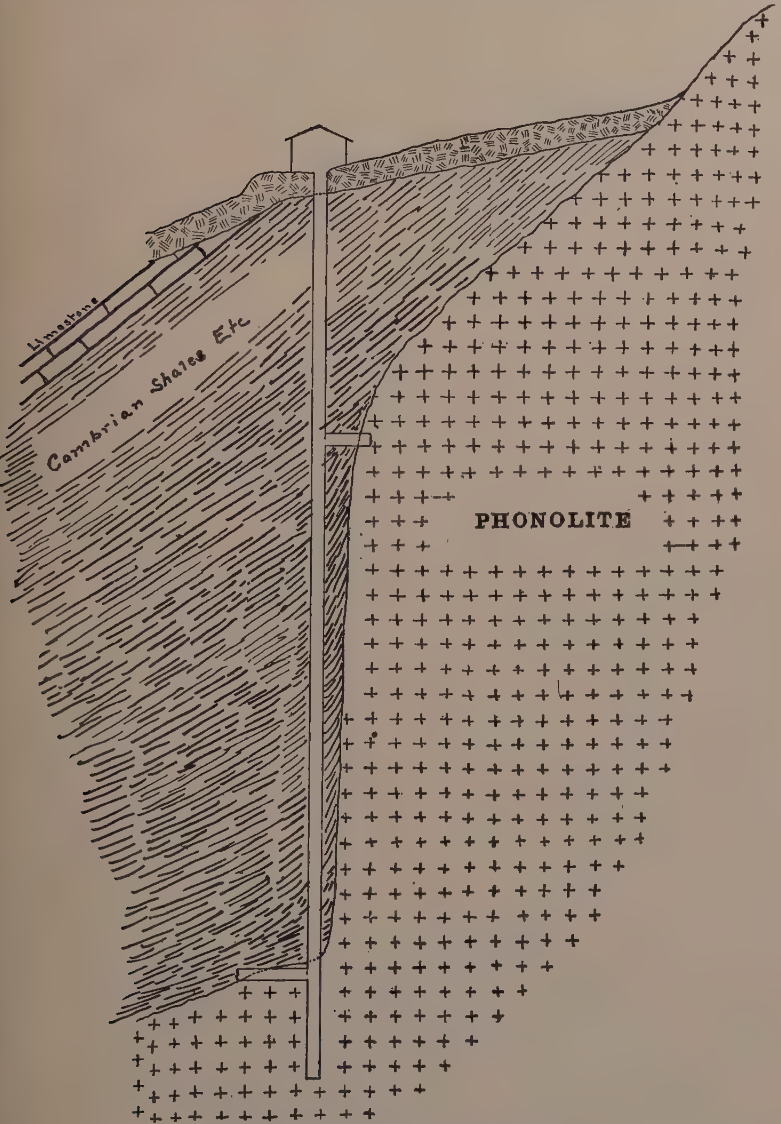

FIG. 9. Section of the Badger Shaft.

distance of twenty-two feet, still dipping away from the mountain, but at a lower angle than before.

A glance at the illustration (Fig. 9) will at once show that it is impossible for so great a thickness of shale to have passed up between the limestone and the phonolite in such a way as to entirely cover the hill, and it would seem to be necessary to assume the existence of a fault along the northern limits of the phonolite in order to explain the facts.

In the crater-like depression on the other side of the mountain the writer was able to find no exposures of shales on account of the great depth of talus, although such have been reported.

A small exposure of Cambrian shales was found at about the center of the connecting ridge between the two triangular ends of the mountain. They rest horizontally upon the phonolite on the very edge of the inside cliff that forms the northern wall of the depression, and attain only a thickness of two or three feet.

At the head of Calamity gulch near Ellington's cabin a drill hole was sunk to a depth of three hundred and seventy feet; it passed through phonolite for the entire distance, and did not penetrate into the shale below. A glance at the model (Plate XIV) will show that the sediments come into close contact with the phonolite escarpment on the north and west, but are comparatively far removed from it on the south and east, where they are exposed on the opposite side of the broad, peripheral valley that extends around the mountain on these two sides. In the bottom of this valley on the south the drill core mentioned above has been sunk in the phonolite, and a small rim of shales is seen between this and the limestone on its southern border. On the east the limestone is exposed in the ridge running out from Elk mountain, and between here and the escarpment the phonolite is visible in the "Spook" shaft. Shales if present are obscured by vegetation and talus.

In neither of these two limestone exposures can an appreciable dip be observed, but as one stands on top of the mountain, a slight incline toward the south and east seems to be present.

It appears probable that the more steeply dipping strata have been cut away by the erosion of the peripheral valley, leaving only the horizontal portions that cap its outside border, its continuity being broken to the southeast by the Elk mountain uplift.

To sum up what has been stated, there are two series of sedimentary rocks, viz., an inner rim of Cambrian shales, and an outer one of massive limestone. Both dip away from the hill on those sides where they closely approach it, so that as one nears the mountain one passes over the upturned edges of the sedimentaries before the phonolite is encountered. On two sides, namely, to the east and south, the sediments have been worn away from the immediate neighborhood of the abrupt escarpment of phonolite, but they may be seen lying above exposures of the latter rock at some little distance. On the west and north the sediments extend to the very foot of the igneous bluff, where they are upturned at a very high angle. On the very top of the mountain a small portion of Cambrian shales still remains. Bearing these facts in mind we may conclude that a mass of igneous rock has found a line of weakness or fracture in the vicinity of Ragged Top mountain, and has forced its way through that until it has almost reached the Carboniferous limestone; that it has broken irregularly across the shales, so as to completely reach the limestone on the west, but has preserved above itself on the north a considerable thickness of shales. On the south a very small thickness of the same formation lies above the igneous rock. Being unable to penetrate, the heavy, massive limestone, the phonolite spread out laterally, forcing its way between the easily cleavable shales and sandstone of the Cambrian formation, and at the same time lifting the entire series of overlying rocks in the shape of a dome. But as the force of the intrusion was strong, and the molten mass very large, the limestone was domed up until it could no longer stand the strain, a series of faults occurred, allowing the fused mass to lift blocks of limestone of irregular shape and size and to fill the spaces beneath them. Subsequent erosion has then removed most of the limestone and revealed the irregular igneous surface, from which the mountain has derived its name.

The conditions at the Badger shaft indicate that there has been a fault along the northern limits of the mountain, and the curved phonolite bluffs on the east and southwest make it seem probable that large blocks of the overlying rock have been lifted by the broad flat eastern mass, as by its smaller western prototype. From the steep inner border of the crater-like depression on the north, we would infer that the limestone was not as far uplifted within its confines, but that the fracture on this side of the hill was of a circular character. The rock was allowed to enter it, and to form the in-curving, dike-like arms that are so conspicuous a feature. The mass of limestone in the depression was large and heavy, and as the force of intrusion could expend itself lifting the smaller masses it did not attain so high an elevation. If we consult the diagrammatic section on Fig. 10, which is supposed to have an east and west direction across the depression, these relations will be clearly illustrated.

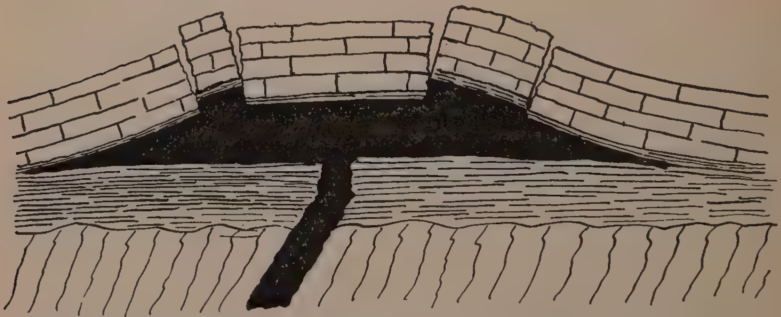

Fig. 10. East and west section of Ragged Top mountains across crater-like depression on the southern slope.

Taken as a whole the Ragged Top laccolite forms a striking contrast to Sugar Loaf hill. The latter is intruded at the base of the Cambrian, and is comparatively flat and low-lying; the former lies almost immediately below the limestone and owes its ragged aspect, to the massive character of that rock.

Terry Peak Laccolite.

Terry Peak has been described by Newton as "the crowning point of an igneous region of considerable extent, having a maximum development in a northwest and southeast direction . . . . Its sharply-pointed summit is the most conspicuous landmark in the northern region of the hills, and is visible from the plains far to the north and east. Its altitude by mercurial barometer is 7,230 feet, and there are but two summits in the hills that outrank it. It rises fully one thousand feet from its base."

If we stand at the summit of the mountain the topographic features may be readily observed. The highest portion comprises a sharp, rather circumscribed, conical mass, falling abruptly for two hundred feet to a broader, more gently sloping portion on the north and southwest, but connected by a steep ridge to a separate and rather conspicuous ridge to the southwest. The slopes of this conical crest are so thickly strewn with talus that the actual contact with the Cambrian shales is completely obscured. Toward the southeast runs a long sloping ridge capped by rounded knolls, and which connects the slope of the mountain, with Deer mountain to the south. To the northwest an extension of the same ridge connects the mountain with the phonolite peak southwest of Green mountain. On the northeast the mountain falls with an even slope in a series of parallel ridges to the comparatively flat country of Ruby basin. On the southwest a broad ridge connects the crest of the mountain with the limestone flats, which separate the gulches of Raspberry and Lost Camp creeks, and into whose headwaters is a very steep fall of eight hundred feet.

As one ascends the mountain from the north, prospect holes have revealed, here and there, exposures of Cambrian shales whose dip gradually increases as we approach the crest of the mountain, until at a point of some two hundred feet or less from the summit, immediately adjoining the talus and débris, it has attained an angle of something over twenty degrees. From this point on to the top of the mountain, and far out onto the divide to the southeast, no break in the continuity of the igneous rock can be observed. The distinct southeastern outlier, which has already been mentioned, is completely made up of this rock, but as we turn toward the southwest a small fragment of Carboniferous limestone is seen resting on top of the divide which separates the forks of Raspberry gulch. Continuing the descent of this divide, we encounter various exposures of Cambrian shales. At a point six hundred feet lower in elevation than the summit of the mountain, these dip at a low angle slightly to the west of south. In the bed of Raspberry gulch, at the point where its two forks unite is a thick sheet of igneous rock, overlain by Cambrian shales, which here dip sharply to the southwest.

The rock from this sheet was not examined microscopically by the writer, and so cannot be said with certainty to be identical with that of Terry Peak.

Again if we ascend the mountain from Foley flat, on the ridge which separates the steep, amphitheatral basin from the forks of Lost Camp creek we find not more than a few hundred feet above the bed of the creek a ridge of unmetamorphosed Cambrian shales dipping at an exceedingly steep angle to the southwest. This is at a distance of nearly half a mile from the igneous crest of the peak, however, and it is doubtful if that has been the disturbing influence. Indeed, as we ascend still further up the divide we may look off into the deep basin to the south, and see the Cambrian in great development, but not in so disturbed a condition.

On the ridge which bounds this basin to the south the igneous rock may be seen running further down toward the flat to the southwest, than it does on the northern and western sides, but still not attaining a thickness of more than three hundred feet from the summit of the mountain. The southeastern side of this ridge, which slopes off into Raspberry gulch was not examined, but from the way in which the igneous talus gives place to sediments (as mentioned above) on this side it is probable that the rock is not exposed there in much greater development. On the northern and northeastern sides of the mountain the

B. & M. R. R. has revealed the character of peak. Extremely deep cuts have been made through the ridges that jut out in that direction, and in them are exposed Cambrian shales and sandstones lying perfectly horizontal. Vertical dikes of a compact, fine-grained, white quartz-porphyry cut the sediments, but no large masses of igneous rock appear to disturb their horizontality. At Terry Station a large dike of quartz-porphyry (different from the rock at the summit of the mountain) is seen on the lower side of the railroad extending down into Fantail gulch. More fine-grained dikes of quartz-porphyry of a vertical character also appear on the side of the railroad at this point.

As we stand at Terry Station and look southeast along the railroad an exceedingly conspicuous perpendicular wall of quartz-aegirite-porphyry can be seen, just above the bend in the roadbed, which curves in around the head of Stewart gulch. (Plate XV.) The rock may be traced northwest along the railroad almost to Terry Station, and in the opposite direction to within half a mile of Aztec. At both of these localities it gives place to horizontal Cambrian strata, but its relations to the shales were not clearly made out. Again, this mass may be traced far up (half a mile) into the densely wooded slope of the second great southeastern outlier of the peaks, and from prominent points within this thicket still other outcrops of the same rock may be seen between. This exposure is probably one of a series of comparatively thin sheets which, with their partings of Cambrian strata, constitute the Terry Peak mass.

The only portion of the mountain of which the writer was unable to make examination is the series of ridges and peaks which connect it with Deer Mountain to the southwest; but from the descriptions of Newton, and from the appearance of the great phonolite masses lying to the west of Englewood, it seems probable that in that direction a great complication of intrusions exists.

There are still two more exposures that seem to throw light on the geological character of the peak; the Snowstorm and Sunset shafts. Concerning the first, Professor F. C. Smith has stated:[1] "The apex of Terry Peak consists of basic quartz-porphyry, and large deposits of talus of the same nature are distributed on its various slopes with a few outcrops of rock in place to the northwestward. Intrusive sheets of the same rock occur, as shown in the following section of the Snowstorm mine shaft, in Nevada gulch, about thirty-four hundred feet northerly from the apex of Terry, and about midway between that point and the apex of Green mountain.

(1)	Porphyry,	124	feet.
(2)	Shale,	10	"
(3)	Porphyry?	85	"
(4)	Shale,	30	"
(5)	Porphyry,	4.5	"
(6)	Shale,	87	"
(7)	Porphyry,	0.5	"
(8)	Lime-shale,	15	"
(9)	Sand-rock,	12	"
(10)	Quartzite,	6	"

This gives a total depth of 375 feet, of which 215 feet consists of igneous rock. No. 1, the only sample in the section I have been able to examine, is unquestionably quartz-porphyry. Of the other igneous rock cut in the shaft, No. 3 was called by the Manager "Porphyry or Trachyte," Nos. 5 and 7 being called porphyry similar to No. 1. Between this shaft and Terry's Peak yet remain the upper beds of the Potsdam (above these cut in the shaft) to a thickness of possibly 275 feet, thus indicating pronounced laccolitic conditions for Terry's Peak."

The Sunset mine shaft is situated at the head of a little valley which runs to the southwest from the north fork of Whitetail gulch, uniting with the latter at a point a short distance below the horse-shoe bend, in the Elkhorn R.R. It is about 1150 feet lower in elevation than the summit of the mountain. From data kindly communicated by Professor F. C. Smith personally, and through Professor Kemp, the writer is able to construct roughly the following section:

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[1] Transactions of Amer. Inst. Min. Eng., XXVII, 410, 1897.

(1) Shales, 15 feet.
(2) Quartz-Ægirite-Porphyry, 160 feet.
(3) Shales, 54 feet.

No. 2. was examined and is described in detail on a later page As compared with the rock from the summit of the peak, it differs only in that it contains quartz as phenocrysts and has a much finer ground mass, also in the fact that it contains few large ægirites, but in their place a greater quantity of fine needles of the same mineral. Hence I would take it to be a peripheral phase of the same massif of which the rock on the summit is the more slowly cooled representative.

To sum up these data :

The crest of Terry Peak is a mass of igneous rock, with the strata on the northwest overlying it within 200 feet of the summit, and dipping away at an angle of 20 degrees. The thickness and extent of this mass seems to increase slightly to the southeast. Sheets of similar rock occur in the Snowstorm shaft, at the head of Nevada gulch, and a sheet of rock which may prove to be of the same character is exposed at the head of Raspberry gulch, to the southeast. Between the Snowstorm shaft and the summit of the mountain great thicknesses of horizontal strata are exposed. Horizontal strata are also exposed in Ruby basin, to the southeast. From these facts we are in a position to interpret the geological character of the mountain. The mass of Terry Peak is probably composed of a series of sills of igneous rock, varying in thickness and separated from one another by partings of Cambrian shale and sandstone. Whether or not these were all derived from the same conduit or series of conduits below it is impossible to say, but such is probably the case. The present topographic summit of the mountain was not then a geologic center of disturbance, but rather one of the thinner sheets intruded from the southeast.

That the capping sill was of great lateral extent seems to follow from the almost granitic character of the ground-mass, from the seemingly great size of the rock mass to the southeast, and most of all from the fact that the mountain has withstood the degrading forces of erosion long after its lesser neighbors have been worn away.

The Needles.

This porphyry uplift is situated some miles to the west of Spearfish creek, between Bear gulch and Beaver creek. It consists of a series of extremely sharp conical peaks, which have a needle-like aspect, and which show the most perfect columnar parting that the writer has seen in the Hills, with the exception of those exposed in the Devil's Tower. The columns are vertical, and are broken across by a jointing, which shows a rough resemblance to the ball and socket jointing of basalt.

Three of these conical peaks are especially high, one of them rising 500 feet above the bed of the creek below.

Viewed from the south they bear, collectively, strong resemblance to a huge dike, but on ascending the highest of them, one is impressed with the almost plug-like character of the mass, The Carboniferous limestone can be seen to the east, north and northwest, forming a wall about the uplift. On the west there seems to be an extension of the porphyry. On the south great blocks of indurated sandstone occur and the Cambrian is extensively exposed in this direction. The Nigger hill Algonkian area is situated to the southwest, and it is probably to this that the exposures of Cambrian are due. In between the lower porphyry hills exposures of Cambrian shale occur, as if in its intrusion the rock had included a portion of that series above itself, and had elevated this to the level of the surrounding limestone. The conical hills would then be the masses which had filled the spaces below uplifted blocks of the massive, overlying limestone. As maps were not available, no complete description of the uplift can be given, but from its general appearance it seems to be in the nature of a vast upheaval with an extremely irregular summit, due to the massive character of the rock beneath which it was intruded.

Crow Peak.

Crow peak has been described by Newton as follows : " Crow peak is a pustular outbreak of volcanic rock through the Red Bed limestone twelve miles northeast from Terry peak. Though it does not rank as one of the highest points of the hills it springs so abruptly from its immediate surroundings as to make it a very conspicious point. Its approximate height above the Red Valley in its vicinity is 1500 feet. As seen from the east or west, it appears to be composed of two peaks closely united ; the southern one is the rhyolite core, while the northern consists of the uplifted sedimentary strata, which are elevated higher on that side. The rhyolite point is conical, with, however, a larger development in a north and southern direction, so that the summit is a ridge several hundred feet in length. Along this barren ridge the rock outcrops prominently. It has a distinct cleavage lengthwise of the ridge, and is divided thereby into plates, which in some places are quite thin.

The steep slopes of the sides are masses of loose and sliding fragments.

The rock is a light gray, compact, tough rhyolite. It has been forced through the sedimentary strata, which, from the Potsdam to the Red Bed limestone, are exposed around the base, and are all more or less disturbed. The Red Bed limestone is least influenced and surrounds the peak in a gentle slope or ledge, while a long low swell or ridge extends for several miles northerly into the Red valley, diminishing and finally dying out entirely. Within a few hundred feet of the peak the Carboniferous is seen in a cañon lying nearly horizontal, while it laps up against the base at an angle 75 or 80 degrees.

The Potsdam is exposed at several places in the cañon, having the usual character, while under the Carboniferous against the peak it stands vertical. It has been more or less completely metamorphosed into a hard quartzite, though none of the other sedimentary rocks appear to be in the least changed by proximity to the igneous mass."

To this description the present writer can suggest no important additions except in regard to the interpretation of the observed phenomena.

The rock seems to be more closely related to the dacites and andesites than to the rhyolites. The outbreak is not pustular but one of the most perfect examples of a laccolite that the region affords. It does not in the least suggest the idea of a "plutonic plug," as Professor Russell, must himself have admitted had he been able to examine it closely.

In addition to these more perfect laccolitic masses others occur which do not form prominent mountains and whose relations are not so simple. Their laccolitic character seems to be unquestionable, although it has been much modified by faulting and subsequent intrusion. Of these the most important is the large quartz-porphyry mass, at the head of Squaw creek, the highest point of which is War Eagle hill.

War Eagle Hill Intrusion.

If we descend into the head of Squaw creek from the B. & M. R. R. we will see that the sides of the deep gorge are here composed of a light brown quartz-porphyry, which stands in abrupt wall-like masses. On top of the hills to the northeast and southwest lie Cambrian shales and sandstones. From the broad top of the first hill one may descend in all directions and find below the thin capping of shales, solid quartz-porphyry, in whose continuity no break can be detected. On the east the Cambrian may be found forming a thin partition between the porphyry and the Algonkian, and as we trace this around to the north it gradually becomes thinner, until, so far as can be observed, the porphyry rests directly on the Algonkian. Again, in the head of East Squaw creek prospecting tunnels have penetrated a small mass of Cambrian, which lies underneath the porphyry at that point. If now we walk southwest from the head of East Squaw creek we pass up over the porphyry and down to the bed of Squaw creek, and across the same rock until we find the shale covering it on the top of the hill. It is again encountered in a thin sheet on the narrow-gauge railroad and may be seen lying on the shale in Annie creek, some fifty feet below. As we follow it around the series of little gulches running into Squaw creek we find it overlying the heavy basal quartzite of the Cambrian in a perpendicular cliff, and apparently running around the hill, to connect with the large quartz-porphyry mass of Gushurst hill. The twofold character of the porphyry mass will be understood if we descend the bed of Squaw creek from the old Portland mill. Here we find the pinkish-brown "Bird's Eye" quartz-porphyry in sharp contact with a deep bluish looking rock which makes the sides of the gorge, until we arrive at the large amphibolite exposures far down the stream. This contact may be traced up on Gushurst hill to the northeast and in the opposite direction up the bed of the gulch for some distance until obscured by talus. The blackish porphyry forms a very irregular intrusion and has tilted up the basal Cambrian conglomerates on the west at an angle of nearly twenty degrees. This westwardly dipping rim of quartzite can be traced from the head of Squaw creek far around out on the divide between Squaw creek and Labrador gulch.

The two varieties of rock when examined under the microscope present little or no difference, except that the feldspars of the darker type are prevailingly square in outline and those of the other generally rounded. The blackish quartz-porphyry of this lower mass underlies the quartzite completely down to Squaw creek, and may be seen again in Labrador gulch. In this vicinity its relations are obscured by so complicated a maze of intrusions that it would be a hopeless task to try to unravel them. The more important facts with regard to the intrusions will, however, be readily grasped, *i. e.*, that there are here two separate quartz-porphyry masses, one of which has been intruded partly beneath the Cambrian and partly above it.

The quartz-porphyry of the lower intrusion is cut by two tinguaite dikes, one in the bed of Squaw creek and of a rather fined-grained character; the other a very coarse dike (described on page 259) which cuts the porphyry both above and below the quartzite, and of which many huge boulders have fallen into the bed of Squaw creek. This dike is very persistent, and can be traced for a distance of nearly one mile.

Red Path Creek Sheet and Laccolite.

Toward the northwest from the summit of Twin Peaks, one may see out on the limestone flat a low conical knoll. Approaching this over the intervening country, are found the flats to be covered by talus of a dark basic hornblende-mica-diorite-porphyry, whose chief component in weathered specimens seems to be biotite. The rock is found sometimes in place, and sometime only as a heavy talus. As one approaches the knoll, the massive outcrops are more pronounced, the hill itself being made up entirely of the rock. From this point it can be traced far down into Red Path creek, which it finally crosses in an abrupt cliff.

On the west bank of the latter creek the limestone dips away from the porphyry at a high angle toward the west, but quickly reassumes its normal inclination. This mica-diorite-porphyry mass has spread out in great thickness and extent toward the east, and appears to have split into sheets of varying size as one proceeds in that direction. It outcrops on the crests of the divides which run toward the northeast into Squaw creek, as far as the west branch of Labrador gulch, and on the higher points of these it is covered by thin cappings of Cambrian shales. Just northwest of Twin Peaks it is cut by a dike of very coarse tinguaite, the extension of which appears on the divide separating Red Path from Squaw creek proper.

Bald Mountain.

To the northwest of Terry peak rises the beautifully rounded dome of Bald mountain, lying between the south fork of Deadwood creek on the north and the deeply carved Nevada gulch on the south. The summit is covered by a considerable thickness of a fine, bluish-looking quartz-aegirite-porphyry, and on the side are exposed the Cambrian shales and quartzites. Many faults occur on the mountain, and dikes, sheets and irregular masses of quartz-porphyry and phonolite are extensively exposed. It may prove to be the remnant of a laccolitic mass, but needs further study.

2. SHEETS IN THE CAMBRIAN.

Second only in importance, and in number far superior to the laccolitic masses, are the sheets which occur in the Cambrian formation. So great is their number throughout the district that it is no exaggeration to say that the thickness of the Cambrian formation has been increased by nearly one-fourth in those localities which are near the centers of eruption. Crosby has remarked[1] with great truth: "It is no uncommon thing to find, as in the district on the east side of Terry peak, known as Ruby Basin, from four to six intrusive sheets in one continuous exposure; the thickness of the Potsdam partings, in some cases, scarcely exceeding that of the eruptive layers." The sheets vary from less than a foot through all thicknesses up to 200 or 300 feet, until we pass by imperceptible gradations into those masses that can be more properly described as laccolites. They vary greatly also in their regularity and persistence, sometimes being short, thick and irregular, and again long, thin and of great lateral extent. The more extended and persistent sheets lie between the heavy and less easily broken members of the Cambrian series, while those which assume a very irregular form are most commonly in the thicker horizons of very fine shales, where fracture is equally easy in all directions.

The largest and most persistent sheet of the district is that which is exposed on the sides of Squaw creek. It originates in a very large dike-like mass of trachytoid phonolite, nearly opposite the mouth of Redpath creek, through which the stream has cut a deep, narrow pathway with precipitous sides. From here it may be traced up along the sides of the creek almost to the mouth of the west branch of Labrador gulch, where, following the dip of the Cambrian, it has mounted high up on the side of the divide. On the opposite side of Squaw creek it cannot be traced so far south, but has attained a much higher elevation by reason of the westerly dip of the shales and sandstones.

Measurements of the thickness of this sheet were not made, but it is probably not less than 200 feet in the thickest portions. Ascending higher on the side of Squaw creek we encounter the hornblende-mica-diorite-porphyry of the Redpath laccolite, which here has spread out into thinner sheets.

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[1] Proceedings of the Boston Society of Natural History, Vol. XXII, p 512.

Again, not far above the mouth of Squaw creek, two sheets, one of mica-diorite-porphyry, the other of a fine grained phonolite, may be observed with a very thin parting between them, dipping with the Cambrian toward the west. Besides these larger masses many smaller sheets, innumerable dikes and irregular masses occur on Squaw creek. In the vicinity of Richmond hill and Ragged butte, two large dikes of quartz-porphyry jut out toward the south, and form exceedingly conspicuous land marks.

Between Crown Hill and Twin Peaks, near the Crown mine, is a sheet of light green ægirite-quartz-porphyry, similar to that of Elk mountain.

Still farther is a prominent knoll formed of a projecting outcrop of coarse trachytoid phonolite of a yellowish color, and not to be distinguished megascopically from a trachyte. Passing down the divide to the northwest, we next encounter limestone, and finally the two-fold conical hill, which has been called Twin Peaks. It is composed of a coarse, rotten quartz-porphyry which forms two rather sharp, conical peaks connected by a somewhat lower ridge of the same rock. On the south and west, 210 feet below the summit, we find limestone, but a little farther around toward the west a prospect hole shows the Cambrian shales, and the same formation is to be found east and northwest. On the west it seems to come in contact with the mica-diorite-porphyry. The tinguaite dike occurring in the Ulster mine can be traced up almost to the summit of the hill by fragmental outcrops, and probably cuts the eruptive forming the hill. No disturbance of the surrounding sediments was observed. The hill is probably the remnant of a laccolite intruded below the limestone of the Carboniferous, and from which erosion has removed all of the sedimentary covering and left only the core of the hill resting in apparent conformity upon the Cambrian shales.

Beyond the mouth of Squaw creek, in Spearfish cañon, about half a mile above Maurice, are two sheets of phonolite. The one nearer Maurice is of a grayish character and indeterminable extent. The other is some distance farther up stream, and is in the form of a very heavy sheet, intruded just below the Carboniferous limestone. It is extremely thick in places and is best exposed where a small stream has cut through it a very deep, narrow gorge, not more than a few feet from the railroad. It is one of the most typical phonolites of the region. No further igneous rocks can be observed in Spearfish cañon until the mouth is reached of Annie creek. Here there is a very thick sheet of a fine-grained phonolite, and the same rock is found in the bed of the creek near the railroad bridge, some distance up stream. Along the railroad, close to Elmore and at other points on the east bank of the creek, are other exposures. Ascending Annie creek one encounters two sheets of phonolite, the lower of which may be seen lying with perfect horizontality on the Cambrian shales at the mouth of Lost Camp creek. It may be traced up the stream until it disappears beneath the shales a little below Davier's cabin. The upper sheet runs far up into Rose Spring creek on the north and around into Lost Camp on the south. Other sheets and dikes of phonolite occur in this locality also.

At the head of the stream is the rounded summit of Foley peak, which is composed of quartz-porphyry. Whether this mountain consists of a series of sheets or is one large mass of igneous rock was not determined.

Lying almost exactly between Foley peak and Green mountain is an irregular sheet of phonolite of considerable extent, which extends down to the railroad near Portland, and was evidently a portion of the same mass that forms the crest of Green mountain, but the connecting portions have long since been removed by erosion.

Beneath the Green mountain mass lie the Cambrian shales in which mine tunnels have been run in all directions toward the center of the hill. None of them, however, encountered any phonolite.

Sheets of quartz-porphyry are also to be seen on the slopes of Green mountain, and a large mass of that rock occurs on the saddle between Green and Bald mountains.

On the slopes of Terry peak, in Nevada and Fantail gulches, and throughout the entire district known as Ruby Basin, sheets of igneous rock occur in great abundance. In the Cambrian west of Englewood there is an enormous mass of fine-grained phonolite of a brilliant green color, which is apparently present in the form of a very large sheet. Another sheet of biotite-phonolite appears southeast of Aztec and covers an extensive area. On the railroad from Aztec to Englewood many sheets of phonolite are seen, and also sheets of a white, exceedingly fine-grained rhyolite, which is intersected by a dark-colored quartz-porphyry in very small dikes.

3. DIKES IN THE CAMBRIAN.

Besides the sheets and laccolites, dikes appear in considerable numbers in the Cambrian. In the Ruby Basin district vertical dikes of quartz-porphyry occur. Some of them are of considerable size, as that which juts out from Terry Station into the head of Fantail gulch. Others are very small.

Phonolite also occurs in dikes throughout the region and when found in contact with the quartz-porphyry always intersects the latter, a relation which proves the phonolites to be the relatively later intrusives. Instances are the long, coarse tinguaite dike near the Rua mine, the dike with east and west strike in Squaw creek below the Gushurst mine, the dike northwest of Twin Peaks and many others.

C. Intrusions in the Carboniferous.

These are comparatively few in number and of limited areal extent. They cannot be classed as dikes, sheets or laccolites, but are more in the nature of thick irregular masses, which seem to belong to none or to all three of these types. The most conspicuous is Elk mountain.

Elk mountain.—This hill is situated on the Carboniferous plateau, something less than one mile, directly east of Crown

Hill. (See Plate IX.) It is elliptical in outline, having its longer development in an east and west direction, and rises about 400 feet from its base. On the east and west it slopes quite gradually down to the Carboniferous limestone, but on the south by a somewhat steeper descent passes into the head of Elk cañon. These relations can be best understood from the model. (Plate XIV.) On the top of the mountain is a ragged exposure of quartz-aegirite-porphyry from which talus has fallen and covered the upper slopes of the hill. Prospect holes have revealed the limestone on both sides of the mountain at a point 170 feet lower in elevation than the summit. At various other points shafts have been sunk, but all have been in the limestone, and with the exception of one on the northern slope, and at a very considerable distance from the top, have encountered nothing but limestone. In this shaft two sheets of from 10 to 20 feet in thickness and with irregular contacts were struck at a depth of about 75 feet.

On the east of the ridge previously mentioned, and in the bottom of Long Valley, extending out across the road, is an irregular exposure of a rock similar in appearance to that on the top of the mountain. It was not, however, examined under the microscope. The only other exposure of porphyry near the mountain is that near the bottom of Calamity gulch, and this is probably connected with the Ragged Top upheaval.

On the east slope of the hill, at a point 300 feet below the summit, quite extensive tunnels have been run. In them the limestone is seen dipping at an angle of 20 degrees toward the northeast. Excepting in this tunnel, no disturbance can be detected in the strata that compose the mountain.

It will at once appear that Elk mountain is not to be considered a typical laccolite. It is a comparatively thin capping of porphyry (170 feet) on a mountain composed almost entirely of limestone—a mountain which owes its existence to the protection afforded by the hard rock above, rather than to elevatory forces acting from below.

The sheets mentioned as occurring in Calamity gulch, on the northeast, and in the bed of Long Valley creek, may be connected with the dike, from which the Elk mountain mass originated, and it is not improbable that this dike is within the mass of Elk mountain. In that sense, then, the latter is laccolitic. It presents, however, no essential difference from the other small, thick-set intrusions in the Carboniferous.

Other Intrusions in the Carboniferous.

On the divide between Calamity gulch and a tributary of Spearfish creek, which runs in a northwesterly direction, is an exposure of phonolite of a very irregular character. It outcrops in an abrupt cliff on the edge of the gulch, and from the flats to the southwest is a quite conspicuous point. On the middle of the divide it is covered by limestone, but is exposed again around the head of the gulch. To the west, on the edge of the cañon, and directly across from Spearfish Falls, is another mass of the same rock. A third and very irregular mass of tinguaite is seen on the edge of the cañon on the Pete Hand flat. Other than these, irregular dikes and porphyry masses occasionally occur in the limestone. Such are especially noticeable in the Ulster mine, which is on the ridge just southeast of Twin Peaks. Here dikes and irregular masses of quartz-porphyry and phonolite appear, and some of them are of considerable extent. All, however, seem to be connected with the Twin Peaks uplift. The only other intrusion in the Carboniferous worthy of note is the large sheet of mica-diorite-porphyry which cuts across from the Cambrian up into the Carboniferous, so as to include a portion of that formation below itself.

B. COMPARISON BETWEEN INTRUSIONS IN THE THREE FORMATIONS.

Perhaps no more striking feature of the eruptive action in the Northern hills can be found than the contrast in form and distribution presented by the intruded masses as they pass from one formatian to another.

The lithological character of the formation has in each case exerted a powerful influence on the form of the intrusion. In the Algonkian areas, where the schists and slates are tilted on end, the lines of least resistance lie in an approximately vertical direction, and we have a great profusion of dikes, conforming without exception to the strike and dip of the slates. Only when the intruded mass has been large and the force of intrusion very great do we find irregularities, and even then the general trend of the masses shows a pronounced parallelism to the lamination of the Algonkian. So soon, however, as the eruptives reach the Cambrian formation a complete reversal of conditions takes place. The lines of least resistance lie now in a horizontal direction, and eruptives on encountering the heavier members of this formation have found it easier to insinuate themselves between the easily cleavable shales and sandstones than to break through the heavy overlying rocks. Therefore we find the predominant type of intrusion in the Cambrian formation to be the intruded sheet. The jointed character of the sandstones and the easy compressibility of the shales between has, however, caused many fractures and faults, resulting in the production of dikes and irregular bodies and modifying the usual horizontal type of intrusion. By such fractures the magmas have been allowed to penetrate all horizons and introduce themselves between the shales wherever they have found an unyielding roof to bar their further progress. If the intruded mass has been large, and the force of intrusion great, not only has the rock spread out between the sediments, but it has domed up those which overlay it, producing a laccolite.

In the Cambrian formation we can distinguish three separate horizons which are most commonly invaded by the eruptives.

1st. That between the Algonkian and the heavy basal quartzitic conglomerate which immediately overlies it.

2d. That underlying the heavy upper quartzite.

3d. Immediately at the top of the Cambro-Silurian, under massive limestone of the Carboniferous.

In addition, sheets occur at all the intervening zones, their choice of horizon being influenced by local variations in the thickness of the alternating shales and sandstones of the Cambrian.

But not only are sheets and laccolites characteristic types of intrusions in the Cambrian formation, but dikes and irregular bodies are very extensively developed in the regions of greatest eruptive activity. There is, however, in the most irregular masses often a readily traceable connection between the form which the eruptive has assumed and the character of the rock into which it has been intruded. An excellent illustration of this can be seen in the railroad cut at Portland. A cut has been made through the upper measures of the Cambrian, revealing a few feet of heavy sandstone, over which lie some 15 feet of Cambrian shales. These are of an extremely fine, fissile, character, separating easily into the very thinnest of plates. A cross jointing has further been developed, so that they break in all directions with equal facility. Into these have been intruded masses of quartz-porphyry which present a very peculiar elliptical form, as if the railroad had cut across the arm-like extension of an irregular eruptive mass. When examined closely, however, they prove to be merely nuclei of comparatively undecomposed porphyry, which are connected with very irregular branching masses. These run out in all directions, but from their decomposed condition and the partial covering of shales, which have fallen from above, they are not to be observed at first sight. Plate XVI is a photograph of one of these masses in which the line between the irregular porphyry and the shales has not been completely obscured.

Not only is there a marked contrast between the intrusions in the Cambrian and the Algonkian, but an even greater one manifests itself as we pass from these formations up into the limestones of the Carboniferous.

Instead of the innumerable intrusive masses that dot the Cambrian areas, the integrity of the limestones is disturbed by very few, for the massive character of the rock, and its great thickness have been an effectual barrier to the upward passage of the igneous rock. Dikes, as, for instance, the biotite phonolite dike in Spearfish cañon, on reaching the Carboniferous have been unable to penetrate it and have become "blind." Where vertical fissures have allowed the igneous rock to penetrate, it has been either in the usual small thick-set intrusion, such as that on Elk mountain or laccolitic masses, such as Ragged Top, Crow Peak or the Needles. The latter are not really intrusions in the Carboniferous, but were formerly covered by it and have been exposed by erosion.

A glance at the sketch map, fig. 11, will bring out these relations. The shaded areas are those covered by the Carboniferous and overlying formations. The unshaded portions are those from which the limestone has been completely removed.

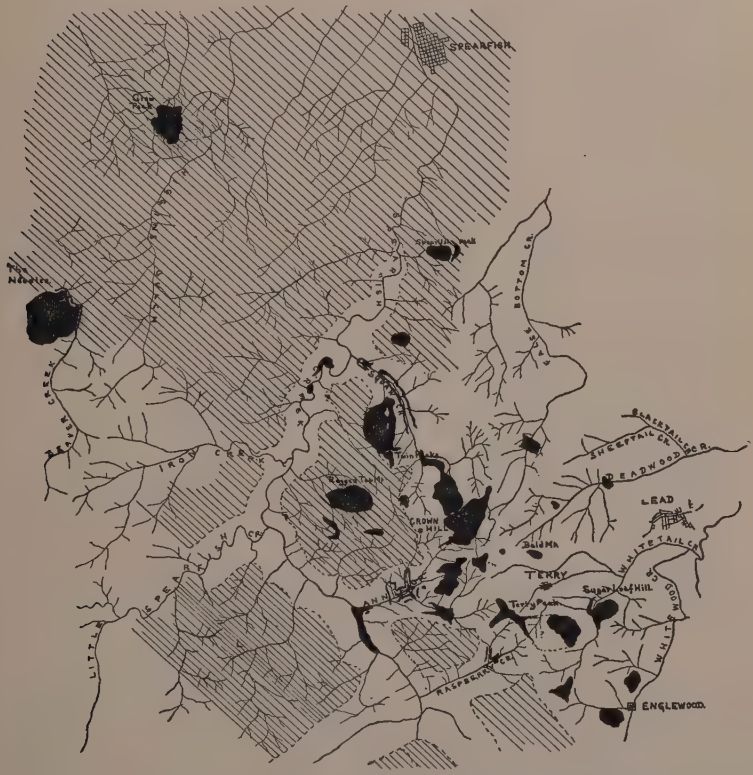

Fig. 11. Sketch map showing relation of intrusions to formations into which they have been intruded. The black portions are the eruptives, the white areas are the Algonkian and Cambro-Silurian, the shaded areas are the Carboniferous limestone.

C. VIEWS OF PREVIOUS WRITERS.

Probably no geological feature of the Black Hills has attracted a greater amount of attention than the eruptive rocks. The number of small igneous peaks there exposed is so great, and they occur so closely crowded together within a comparatively limited area, and show such unique structure, that it is quite natural that, even with the very superficial examinations given to them, they should have become widely known.

Newton was the first to examine them, and was impressed with the extremely local character of the disturbance which they had produced upon the encompassing sediments. This fact, taken together with the manner in which the sediments were upraised about their sides, led him to account for them by the theory of pustular eruptions. He considered them as eruptive masses that had broken up through the overlying rock, reaching up to and extending beyond the surface so as to leave the strata uplifted around them, just as are the broken edges of a piece of paper when it has been penetrated by a pencil. Such an assumption, as Professor Crosby has stated,[1] necessitates a degree of viscidity which it is difficult to imagine in any magma that has reached the surface, for in no case has the rock flowed outward from the center of the eruption.

Some years after Newton's report had been made, Professor Crosby visited the Hills and, in company with Dr. F. R. Carpenter, studied the various formations exposed.

In a short discussion[2] of the igneous phenomena he calls attention to the occurrence of true laccolites, a form of intrusion unknown at the time of the Newton survey; and of vast numbers of sheets and dikes occurring in the hills together with them.

He then shows that the existence of these thin, conformable, intruded sheets necessitates a degree of fluidity in the rock which is entirely at variance with Newton's theory.

Finally Professor I. C. Russell visited the region. He did not study the same portion of the country as Crosby, but confined his attention to several of the more prominent igneous uplifts that are far removed from the axis of the hills. Of these he studied four: Sundance hill, Mato Tepee, Little Sundance hill and the Little Missouri buttes. For the others he referred to the accurate descriptions of Newton. Like Newton, he was impressed by the local nature of the disturbances and by the uplifted strata around them.

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[1] Proceedings of Boston Society of Natural History, Vol. XXII., page 513.

[2] Op cit. Page 512.

He further calls attention to the entire absence of dikes and auxiliary intrusives in their neighborhood, and accounts for their form by the assumption that they were "plutonic plugs" injected into overlying strata from below with a force sufficient to perforate portions of the sediments, but still buried deep below the surface. His theory, as that of Newton, implies a viscidity such that the formation of fluid intrusions like sheets and dikes was an impossibility, and differs from the first theory only in regard to the large amount of superincumbent strata. It is in part owing to the great pressure exerted on the intrusion by this overlying rock that he attributes the viscidity, impossible in a surface eruption. In a second paper he discusses the general nature of intrusions and elaborates his theory of "plutonic plugs" from phenomena observed in the hills. The paper is too long for quotation, and for a complete review the reader is referred to the same, but the points with which we are mainly concerned are these:

> The distance to which an intrusion will extend laterally is dependent largely on the consistency of the intruded rock; if fluid it will extend to great distance, as the Palisades diabase; if slightly viscid it will produce a less extended upheaval and will from a laccolite; and, finally, if very viscid it will form an extremely local upheaval, as the "plutonic plugs" of the Black Hills. Such viscidity is a function: *First* of the chemical composition of the rock, acid rocks being more viscid than basic; and *second*, of the pressure exerted by the depth of burial, the more deeply buried being the least fluid. Newton has shown that the rocks forming the peaks discussed are acid rocks, and also that the strata which formerly covered them were of a probable depth of 4 000 feet. Both conditions for the existence of "plutonic plugs" are then fulfilled. The peaks studied are of this character, and from the writings of Newton the others seem to be.

Of the peaks discussed in Russell's paper the writer has studied Crow and Terry peaks, but in addition has described Sugar Loaf hill, the Needles, Ragged Top mountain, Elk mountain and other igneous masses. What further study may reveal in the cases of far outlying peaks, as Custer peak, Bear butte, Inyan Cara, Mato Tepee and the Little Missouri buttes, of course, cannot be stated, but from the fact that these peripheral bodies were forced up beyond the level of the Carboniferous the conclusions adduced would seem to be equally applicable to them.

In addition to the above cited papers, a short report on the geology of the same portion of the hills studied by the writer appeared in the transactions of the American Institute of Mining Engineers, in which mention is made of Terry peak and Sugar Loaf hill as laccolites, and also of the numerous intruded sheets and dikes of the district. As the paper is chiefly concerned with the ore bodies, however, there is no discussion of the structural relations of the eruptives.

The fact which strikes one most forcibly in the studies of those who have so far written on this subject is that their conclusions were the results in either case of the phenomena observed within the limited district they studied. Newton's observations, from the hurried nature of his survey were necessarily, confined to the larger and more conspicuous eruptive bodies, and especially the unique hills that lie in the periphery of the main Black Hills uplift. The smaller sheets and dikes that would imply a degree of fluidity inconsistent with his hypothesis were overlooked by him. Even more is this true of Russell whose studies were made where the absence of dikes and smaller intrusions seemed phenomenal, and who was able to see only the peaks farthest removed from the main eruptive center of the hills. Crosby, on the other hand, made his observations directly in the heart of the eruptive region, and was strongly impressed by the vast numbers of small dikes, sheets and irregular bodies that intersect the sedimentary rocks, and thus was led to regard the intrusions as a very fluid series.

D. CONCLUSIONS.

If we bar out the pustular theory of Newton, which is rendered improbable by the complete absence of superficial features in the rocks composing the igneous peaks, we are left with two almost contradictory assumptions—one that the magmas intruded were of great viscidity, and hence took the form of "plutonic plugs"; the other that they were extremely fluid, and were thus enabled to spread out into thin sheets. How can we reconcile these opposing hypotheses, and the facts advanced in support of them? If we are to accept Russel's view that the outlying masses of Bear butte, Mato Tepee, etc., are "plutonic plugs" it is necessary to explain the occurrence of the vast number of intrusive sheets and dikes in the region about Terry peak.

It might be suggested that the Terry peak region is near the center of the uplift, and that for this reason the pressure of the overlying sediments may have been relieved by erosion, while the sediments remained in their full development on the outlying portions of the hills. This then might enable us to explain the predominance of fluid magmas in the central region and more viscid upon the borders of the hills, on the ground that the latter were the more deeply buried. The laccolitic peaks are not, however, confined to the borders of the hills. Crow peak, which is one of the most typical and is cited both by Newton and Russell, is situated well up on the border of the eruptive center. The uplifts known as the Needles, Terry peak and Ragged Top (and the latter is more plug-like in its aspect than any of the other masses that the writer has seen) are directly in the center of the region most thickly seamed with dikes and sheets.

Again, we cannot explain the occurrence of these laccolitic masses by the argument that they are of a more acidic rock than those which form the sheets and dikes in their immediate vicinity, for these latter types of intrusives frequently range well up over 70 per cent. in silica. In the case of the Ragged Top mass, moreover, widespread, thin and markedly conformable sheets of a rock, which is chemically and mineralogically almost precisely similar, are found lying between the horizontal Cambrian shales not more than a mile distant. In the opposite direction in Squaw creek, at even less distance, dikes and sheets of phonolite occur in great numbers. Again the rock of Crow peak may be duplicated in many sheets and dikes not far distant, as may also that which forms the Needles. Can we then imagine two rock masses intruded at the same time, under the same conditions, and of the same chemical composition, to be of a highly fluid character in one place, and sufficiently viscid to form a "plutonic plug" in another at no appreciable distance?

But if we are not to explain the form of these larger intrusions by the assumption of a high degree of viscidity, we most look elsewhere for the causes that have determined it, and the explanation is to be found in the character of the formations into which the magmas have been intruded, and the local violence of the force which has intruded them.

Attention has already been called to the contrast between the form of intrusions characteristic of the three separate formations—Algonkian, Cambrian and Carboniferous—to the predominance of dikes in the slate areas, of sheets and laccolites in the Cambrain, and to the comparative lack of intrusions in the limestone formation. The last named are very limited in character, or else intruded in a formation below, and exposed above the limestone area by the erosion of the uplifted covering. The lines of least resistance in the first instance have been vertical, and the only type of intrusion has been dikes; in the second they have been horizontal and sheets have resulted, and when finally the Carboniferous has been reached, the massive limestone has been so resistant a formation that it has prevented the further passage of the igneous rock. Where the force of intrusion has been more violent, however, and the mass of intruded material great, there has not been the same opportunity for lateral expansion and the mass has domed up the more resisting beds, sometimes only slightly, forming a gently sloping laccolite, sometimes to a much greater degree, so that the elasticity of the overlying rock, which would naturally be less than that of the thinly-bedded shales below, has been exceeded ; faults have sometimes taken place, and the intruded mass has lifted up large blocks of sediments and filled the space below them. Erosion has then removed the coverings and left us the "plug-" like and laccolitic masses. In the case of Ragged Top, the plug-like aspect seems almost unquestionably due to the massive character of the limestone. With the Needles this is also true. In the case of Crow peak no faulting seems to have occurred, but the intrusion is of the same general type. Sugar Loaf hill is a true laccolite.

If we bear in mind the influence which the 600 or 800 feet of massive Carboniferous strata have exercised on the rocks intruded below—first by virtue of their position over a thinly bedded, fissile series of shales, such as the Cambrian, and second by virtue of their massive character—we can more readily understand the unique nature of the intrusions that form the outlying peaks of the Black Hills region. The absence of dikes and small auxillary intrusions is thus accounted for, because only those intrusions which have been very strong and locally violent have been able to penetrate beyond this heavy formation. Where erosion has removed this series the intrusives are exposed in great abundance and probably exist in equal profusion in the Cambrian shales far below the existing exposures of the outlying peaks.

Causes Influencing the Formation of an Igneous Intrusion.

From these observations we may classify the causes that have influenced the form of the intrusions as follows :

- Internal
  - A. Fluidity and viscidity
    - 1st. Due to pressure exerted by overlying rocks.
    - 2d. Due to chemical composition of the intruded magma.
  - B. Volume of magma intruded.
- External
  - C. Lithological character of rocks into which the mass has been intruded.
  - D. Violence of force of intrusion.

It is to the first of these causes that Russel attributed the peculiar "plug"-like form of the Black Hills intrusion, but to the other causes he does not refer. That he would have modified his views very much had he been able to see the eruptive region of Terry peak is unquestionable. It is further not to be doubted that the fluidity of a magma has a great influence on the amount of lateral expansion, but that seems to have been a minor factor in all of the Black Hills intrusions.

Let us now briefly consider the other causes. It is at once obvious that if the amount of fluid rock is large, other considerations being equal, there will be a greater tendency to dome the overlying beds than with a small mass, which may easily spread out along horizontal strata. If we then consider the violence with which the fluid is injected this will be the more evident. With a great force slowly applied, and acting through a long period of time, opportunity for lateral expansion will be afforded even to a large amount of fluid and long, thin sheets will result.

If, on the other hand, the force be violent and rapidly applied, however fluid the magma may be, its amount will be greater than can expand in the given time and a doming of strata or even a rupture will result.

Most important of all, however, are the influences of the rocks into which the magmas are intruded; and in the areas which the writer has studied, this has been almost without exception the determining factor of the form assumed by the intrusion.

2. *PETROGRAPHY OF ERUPTIVE ROCKS.*

A. SUMMARY.

The crystalline rocks of the Black Hills were studied by Caswell and described by him in the report made by the Newton Survey in 1874. Considering the very elementary condition of petrographic knowledge at the time this work appeared, the descriptions are extremely accurate, and show unusually painstaking labor. Since that time, however, studies of soda-rich rocks in other localities have made possible a much more accurate determination of phonolitic rocks than was then possible.

Caswell's report and rock determinations made by Pirrson besides those of Professor F. C. Smith have attracted the attention of petrographers to this region and it has been supposed that investigation would show the occurrence of rock types of unusual interest. Such has proved to be the case.

The series of eruptive rocks is quite a varied one. The different types collected by the writer were all gathered from a rather restricted area, but even so show many different varieties.

The following classification has been followed in the description of the eruptive rocks:

OF POST-CRETACEOUS AGE.

- *Grorudite family.*
  - Quartz-ægirite-porphyry.
- *Phonolite family.*
  - Tinguaite.
  - Phonolite.
  - Trachytoid phonolite.
- *Rhyolite family.*
  - Quartz-porphyry.
- *Andesite family.*
  - Mica-diorite-porphyry.
- *Dacite family.*
  - Dacite.
- *Diorite family.*
  - Tonalite.
- *Lamprophyre family.*
  - Augite-Vogesite.

OF PRE-CAMBRIAN AGE.

- Amphibolites.

POST-CRETACEOUS ERUPTIVES.

Grorudite family.

The grorudite family comprises a series of rocks of highly alkaline character whose constituents are: orthoclase, quartz, ægirine-augite and ægirine. In some types albite, microcline and biotite appear as accessories. In the types resembling most closely the rock described by Broegger as grorudite, quartz is confined to the ground-mass. In the other types quartz appears in large and numerous phenocrysts, and as this constitutes a difference between these types and any rock heretofore described the name quartz-ægirite-porphyry has been employed. These rocks average about 72 % SiO_2. Six types are described.

Phonolite family.

The phonolite family includes an extended and varied series of rocks rich in soda and forming the more basic phase of the quartz-ægirite-porphyries. They are composed of orthoclase (and probably some anorthoclase) microcline, ægirine-augite, ægirine, nepheline, nosean, with accessory hauyne, biotite, magnetite, titanite and melanite garnet. The accessory minerals do not occur in the same specimen but appear separately in single types.

The rocks of this family have been divided for convenience of description into three groups. The tinguaites are those in which an unusually marked interlacing of ægirine needles is present in the ground-mass. Nepheline as a rule can be detected in them only by gelatinization and never occurs as phenocrysts. They contain little or no ægirine-augite and are prevailingly fine-grained. The phonolites contain more or less abundant crystals of nepheline easily identified by optical methods and are mostly rich in nosean. The interlacing network of ægirine needles is not pronounced. The trachytoid-phonolites show a great increase in abundance of orthoclase, are comparatively coarse-grained, show large crystals of ægirine-augite but little ægirine. Nepheline is present only in small quantities and is then in the ground-mass as isolated interstitial masses. They indicate a transition toward the trachytes.

Rhyolite family.

The quartz-porphyries of this division are a series of rocks with very varying texture. A fine-grained ground-mass of quartz and feldspar with phenocrysts of orthoclase, plagioclase and quartz are characteristic. In one type quartz was confined to the ground-mass. The dark silicates are usually too decomposed for identification, but when recognizable are hornblende and biotite. The series varies in the amount of SiO_2 present from 65 % to 76 % or 78 %. Five types are described.

Andesite family.

Under the andesite family have been placed the diorite porphyries of which there are quite extensive developments throughout the district. They are rocks of a moderately dense texture and of quite basic character but markedly porphyritic and of undoubted intrusive nature.

They exhibit a fine-grained groundmass of plagioclase feldspar, accessory quartz and much chlorite, phenocrysts of plagioclase, orthoclase, hornblende and in most cases biotite. The hornblende is very generally altered to chlorite. Orthoclase in instances becomes so abundant as to cause the rock to resemble the syenite-porphyries. Analysis showed about 55 % SiO_2.

Dacite family.

The dacites exhibit a fine-grained groundmass of quartz and orthoclase in which are embedded phenocrysts of plagioclase, orthoclase and quartz. Auxiliary titanite, magnetite and biotite are generally present. No analysis of the dacites were made, but one type showed an extremely large amount of quartz.

Diorite family.

Tonalite.—Only one exposure of this rock was found and that an extremely large dike in Deadwood Gulch. It is a gray rock composed of hornblende, plagioclase, quartz, biotite and accessory orthoclase and is of granitoid texture, showing a slight tendency to automorphism in the component minerals.

Basalt family.

Augite-Vogesite.—This rock occurs in small dikes west of Spearfish cañon and is composed of a fine automorphic aggregate of augite and feldspar with accessory hornblende and magnetite. It is the final and basic representative of the soda-rich magma that constitutes the principal Black Hill's eruptive series.

Pre-Cambrian eruptives.

Amphibolites.—These constitute a series of basic rocks intruded in the Algonkian series and metamorphosed with them.

They consist of meta-diabases and meta-gabbros whose chief components are plagioclase feldspar, hornblende of the variety *uralite* and accessory ilmenite, calcite, apatite and quartz. Cores of large dikes show uralite masses with augite kernels, furnishing a clue to the original character of the rock. Such cores pass towards the periphery with increasing schistosity, proceeding by insensible gradations into chlorite and hornblende schist.

DETAILED DESCRIPTION.

1. **Quartz-ægrite-porphyry.**

This rock is of an exceedingly interesting character as it corresponds exactly in some cases to rocks in Norway, described by W. C. Broegger, as *Grorudite.* In their general appearance these rocks are massive and homogeneous. They range in color from a light greenish gray to almost a white in the more coarse grained and porphyritic varieties. The texture varies from almost completely aphanitic, through porphyritic up to one almost granitoid. In some varieties the quartz cannot be observed in the field, but two very interesting occurrences exhibit very large and numerous phenocrysts of quartz, which have led previous observers to class them with the rhyolites.

The quartz-ægirite-porphyries will be described under the following types :

1. Lost Camp Creek type.
2. Elk Mountain type.
3. Terry Peak type.
4. Annie Creek type.
5. Sunset Mine type.
6. Bald Mountain type.

1. Lost Camp Creek Type.

Megascopic Appearance.—As seen in the field this rock is a light greenish gray and is very fine-grained. The phenocrysts consist of orthoclase, in sparsely scattered crystals, and of very small ægirines which may be seen distributed through the rock, forming here and there a noticeable dark speck or needle-like crystal. The groundmass which constitutes almost the whole body of the rock is a light grayish green, having a vitreous lustre, the color being due to the ægerine needles, and the lustre to the innumerable, fractured quartz grains.

The feldspar forms both phenocrysts and the smaller crystals of the groundmass and is invariably automorphic. Most of the crystals possess a kaolinized rim and none are twinned. The cores of many of these feldspars consist of quartz. Ægirine-augite occurs in sparsely disseminated crystals throughout the groundmass, and seems to have preceded both the quartz and the feldspar in the order of crystallization. Ægirine is present throughout the groundmass in fine acicular crystals exhibiting the customary frayed extremities characteristic of the rocks of the tinguaite series. The absorption is green to nearly colorless and the extinction is invariably parallel. At times these fine needles penetrate the quartz grains and the feldspar, but for the most part they fill the interstices.

Quartz is confined to the groundmass of which it is the chief constituent, the remainder being composed of small square crystals of feldspar and small needles of ægirine. The quartz is very clear, little if at all fractured, and apparently is the latest formed ingredient of the rock.

Microcline, albite, microperthite and hornblende are absent, the last mineral being characteristically lacking in this and most of the other post-Cretaceous intrusives from this region. The rock differs from Broegger's type grorudite in the absence of all of the last named minerals, and but for the predominant ægirine might better be classed with the soda rhyolites than the grorudites.

A silica determination of the type gave SiO_2 71.55.

2. Elk Mountain Type.

Megascopic Appearance.—This rock is much coarser-grained than that from Lost Camp creek, and is markedly porphyritic. The phenocrysts are numerous, and for the most part are sanidine. They are very much decomposed, and replaced by secondary minerals, the alteration having proceeded from within outwards, filling the interior with a maze of highly polarizing zeolites or interlocking crystals of secondary quartz. The borders of the crystals are, however, as a rule left intact, showing merely a slight kaolinization. Where the phenocrysts are in a perfectly fresh condition, many of them are seen to be microcline, a core of which usually remains, even in the more decomposed examples. The microclines show a marked contrast to the sanidines in that the decomposition seems to have proceeded from without inwards. In some cases a kaolinized rim of sanidine encloses an intermediate zone of alteration products, within which again may be seen a kernel of microcline (Fig. 12). The larger feldspars show inclusions of perfectly bounded crystals of ægirine-augite. In no instance, however, are the feldspars penetrated by the fine ægirine needles of the groundmass.

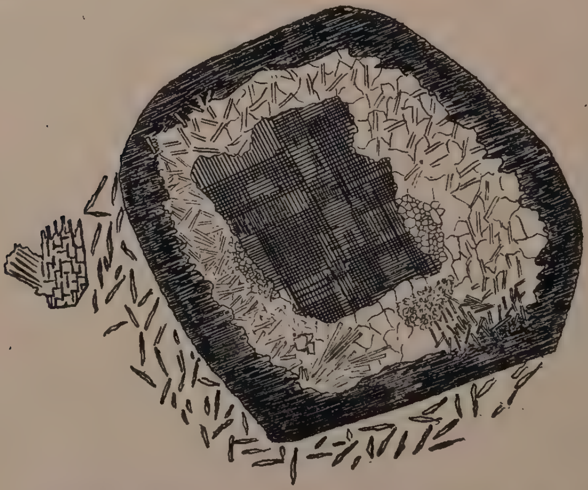

FIG. 12. Phenocryst of feldspar from quartz-ægirite-porphyry showing kernel of microcline, rim of kaolinized feldspar and intermediate zone of alteration products.

The feldspars of the groundmass, when, undecomposed, are with difficulty to be distinguished from the quartz, but where they are of considerable size, or slightly kaolinized, they show an invariable automorphism. They are penetrated by the ægirine needles of the groundmass, as also are the quartz grains.

Bisilicates are present in two distinct varieties which present no essential difference from those in the phonolite family. A more extended description of them will be found under the discussion of the latter rocks, but a brief description is inserted here to render the account of the quartz-ægirite-porphyries complete. The two varieties are :

Ægirine-augite in large automorphic crystals, and fine needles of ægirine, which penetrate all individuals of the groundmass indiscriminately. The ægirine-augites are prevailingly perfect in their crystal outline.

$$\acute{c} : \mathfrak{c} \ 78°, \quad 76°, \text{ and } 75°.$$

A very strong pleochroism is generally exhibited and is greenish-brown, parallel to $\mathfrak{c}$. and deep bluish green parallel to $\mathfrak{a}$.

Colorless, non-pleochroic cores of augite are frequently observed.

The ægirines of the groundmass exhibit in their pleochroism a much deeper green, and are invariably parallel in their extinction. They exhibit both shredded extremities, and crystal terminations. At times they are seen in bundles grouped radially around some earlier formed large crystals of ægirine-augite, and then seem usually to possess very perfect terminations. The breadth sinks at times to a mere thread, so that the color of the mineral can be distinguished only by the aid of the high power objective.

The quartz is confined entirely to the groundmass and differs in no respect from that in the rock described from Lost Camp creek. This rock shows in most respects a very close resemblance to the grorudites described by Broegger. We have, however, again to call attention to the entire absence of hornblende and albite.

Chemical Composition.—A partial analysis is given below. No. I is quartz-ægirite-porphyry from Elk Mountain. No. II is from Broegger, and is a grorudite from Kallerud.[1]

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[1] Die Eruptivgesteine des Kristianiagebietes, p. 49.

	I.	II.
SiO_2	72.25	71.35
Al_2O_3	15.01	12.21
Fe_2O_3	2.05	4.53
FeO	not det.	1.14
CaO	2.06	0.22
MgO	trace	none
Na_2O	not det.	6.51
K_2O	not det.	3.22
H_2O	not det.	
Loss	0.002	0.33
MnO		0.78
TiO_2		0.50
		100.79

It will at once appear that in general the correspondence between the two is quite close except that the alumina and the lime are much higher in the Elk mountain rock than that from Norway.

3. Terry Peak Type.

This rock has been described by Caswell in his report on the Black Hills, but, except to call attention to the coarse granitic appearance of the groundmass, he has not gone very far into the description.

Megascopic Appearance.—The rock is of a mottled appearance and a grayish-green, almost white color, the greenish tinge being due to the presence of large phenocrysts of ægirine which frequently show a cross section of $\frac{1}{16}$ inch in diameter.

Microscopic Characters.—Under the microscope the rocks are seen to consist of a mass of sanidine phenocrysts closely packed together, embedded in a groundmass of quartz and orthoclase. Through this are also scattered in greater numbers than in any of the rocks of the type yet described phenocrysts of ægirine-augite. The latter are sometimes perfectly bounded, but in the majority of cases show an irregular outline, due to the grouping of the smaller ægirines about them, either in parallel orientation with the main mass or radially like the spicules of a radiolarian.

The fine needle-like ægirines seen in the groundmass of the Lost Camp creek and Elk mountain types, are almost if not completely absent. The feldspar phenocrysts are but little decomposed, and then the alteration seems to be only a slight kaolinization, although secondary quartz was observed in one or two of the more decomposed specimens.

The feldspar of the groundmass is partly automorphic, and partly contemporaneous with the quartz in the order of crystallization. It can be easily distinguished from the quartz by its cleavage and kaolinized appearance. A few small automorphic crystals of a very acid plagioclase are present.

The chief difference between this rock and that of the two types previously described is the greater predominance of the sanidine and ægirine-augite phenocrysts and the almost complete absence of the network of minute ægirine needles from the groundmass, the smaller ægirines being confined chiefly to the hair-like enlargements of the larger crystals. Microcline also is absent. The quartz shows no unusual characters. A silica determination made by Caswell shows SiO_2 71.13 per cent.

4. Annie Creek Type.

From the Terry peak type we can pass to that from the head of Annie creek by a very slight gradation. The rock described was taken from the conspicuous dike-like mass, northeast of Foley peak. In the Terry peak type, as in all of the others yet described, the quartz is wholly confined to the groundmass. In this rock, however, we find large and quite numerous phenocrysts of quartz, which range from $\frac{1}{16}$ inch to as much as ⅜ inch, and in rare instances reach ½ inch in diameter. The average is about ¼ inch. They are but little rounded by absorption and exhibit the usual bi-pyramidal character. In many instances a marked zonary banding may be observed, even in the hand specimens.

When examined under the microscope this banding is seen to be caused by the parallel arrangement of a mass of feldspar inclusions, most of them orthoclase, but one or two of them albite. (Fig. 13.)

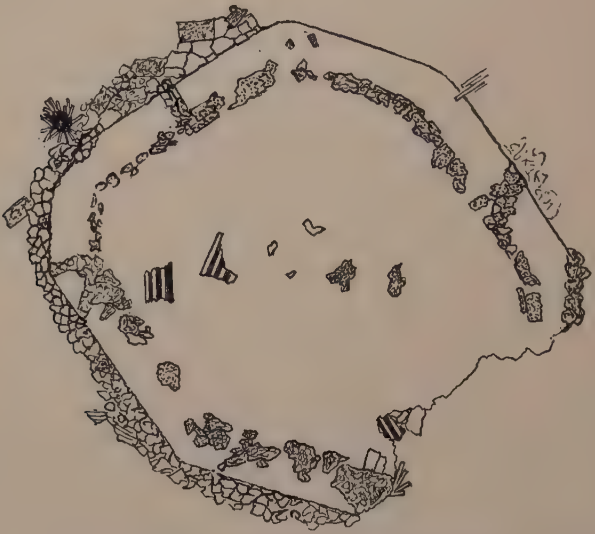

FIG. 13. Zonally arranged inclusions in quartz phenocryst from quartz-ægirite-porphyry; Annie creek type.

5. Sunset Mine Type.

This rock is perhaps the most interesting of the series.

Megascopic Appearance.—It is a porphyritic rock, dark colored in the fresher specimens, and shows large phenocrysts of orthoclase and quartz. The quartz crystals are large, often ⅜ inch in diameter, and much rounded by resorption, and are in many cases elongated; sometimes so much so, that the length will be fifteen times the breadth. When drawn out in this manner, the phenocrysts all lie with their longer axes in the same direction.

Microscopic Characters.—The feldspars are orthoclase, frequently fractured and much resorbed. The cores of the crystals are quite clear but the borders contain inclusions, and seem to have been formed later than the main body of the crystals.

Zonary banding and twinning after the Carlsbad law are exceedingly common. Inclusions of albite occasionally occur in square, almost automorphic crystals. How much of the sanidine may prove on closer study to be anorthoclase cannot be said, although it is exceedingly probable that in a rock containing soda pyroxene in such amount, there may be a considerable quantity. Triclinic characters could not be determined in any of the phenocrysts observed in the rock, and it remains for careful chemical investigation to prove the development of this variety of feldspar.

Phenocrysts of an exceedingly acid plagioclase are also present in considerable quantity, but are very small as compared with the larger sanidines, being only observable with the microscope. The maximum angle, measured in sections perpendicular to albite lamellæ, varies from 4 degrees to 5 degrees. The crystals are scattered here and there through the groundmass and, from their inclusion in the later phenocrysts, they seem to have been formed very early in the consolidation of the magma. The groundmass of the rock is exceedingly fine grained. It consists of a doubly refracting granular aggregate which is penetrated in all directions by needles of ægirine, the latter far exceeding the other individuals in size. How much of this groundmass is quartz and how much feldspar, it is impossible to say, but, judging from the general analogy of the rock with that of Terry peak, to which it seems quite closely related, it is probable that much quatrz is present. The quartz-phenocrysts, which constitute the most noticeable as well as the most unusual feature of the rock, are extremely large, varying from $\frac{1}{16}$ to—in rare instances—½ inch in diameter. They are strongly contrasted with those of the Annie creek mass, in that they are very much resorbed, for the groundmass frequently extends far into them in bottle-shaped embayments. Fractures have often allowed the groundmass to fill the interstices between the broken portions.

The bisilicates are present in two generations; the larger automorphic crystals of ægirine-augite, and the finer shredded needles of ægirine, which in the specimen from the shaft are present in great abundance. The former exhibit the usual augite core, at times completely lacking in pleochroism, surrounded by a border of a greener hue, until we have encircling all, a rim of deep green pleochroic ægirine. This outer border often contains inclusions, and is the last formed portion of the crystal. In the specimen from the sheet on the Burlington and Missouri River R. R. above the mine the smaller needles of ægirine are much more infrequent, and the larger phenocrysts are well developed, some of them attaining the size of ¼ inch in diameter. The only other mineral noticed in this rock was biotite, which is seen sometimes filling the cavities left by the decomposition of the larger crystals of ægirine to whose outline it frequently conforms. It occurs chiefly in the rottener specimens, and is probably an alteration product.

6. Bald Mountain Type.

A very peculiar variety of quartz-ægirite-porphyry is that exposed on the summit of Bald mountain. It is the most unusual rock that the writer has observed from the hills.

Megascopic Appearance.—In the hand specimens it has a rather dense texture, and a light greenish white color. Sanidine phenocrysts are sparsely scattered through it, but rarely attain the diameter of ¼ inch. Quartz phenocrysts appear at rare intervals. The main body of the rock is a light greenish white groundmass with rough trachytic appearance, and closely resembles a tuff or sandstone.

Microscopic Characters.—The microscope shows the following minerals: *Orthoclase, quartz, plagioclase and ægirine.*

The orthoclase phenocrysts show no unusual features, except that they contain many inclusions of plagioclase and a few fragments of earlier formed sanidine. The groundmass, however, is extremely peculiar, as it is composed almost wholly of automorphic quartz crystals of uniform size. These are square, hexagonal, or triangular in sections and average .012 mm. in diameter. They give all tests characteristic of the mineral. The centers of the crystals are usually free from inclusions, but as the border is approached a maze of extremely minute ægirine needles piled up after the manner of a snake fence, are to be observed, and follow with great faithfulness the crystal boundary of the section, but leave between that and themselves a clear rim free from inclusions. The interstices between the quartzes are small but filled by a kaolinized material, which is interpenetrated by a confused maze of the same minute needles of ægirine. These can be best distinguished with the high power. They are not shredded as are the larger varieties, but are terminated. From their extreme minuteness, it is impossible to observe any pleochroism or to determine their optical properties other than to note the parallel extinction. The other constituent of the rock is plagioclase. It occurs in crystals which generally show complete crystal boundaries, but are slightly decomposed at the borders. Measurements on twin lamellæ showed a maximum extinction angle of about 19 degrees, which places the feldspar among the oligoclase andesines.

2. Phonolite Family.

Of all the rocks developed within the district studied, perhaps none attain an extent and importance equal to that of the phonolites. The quartz porphyries are the nearest to them in abundance and in the districts outside of the area mapped probably show a greater development than has been here observed. The relative abundance of the two rock types has not been adequately represented on the map, for the quartz-porphyries occur so frequently in small dikes, sheets and irregular masses that it has been possible to indicate exposures hardly equal to one-half of their actual number. The phonolites, on the other hand, occur in large masses and dikes, which, although exceedingly numerous, are almost invariably fresh and, being easily differentiated from all other types of rock, may frequently be traced for great distances. They intersect all the other eruptives with which they come in contact.

The phonolite family, as developed in the district mapped, includes a series of rocks of so extremely varied a range in texture and appearance that it would be utterly out of the question to attempt a separate description of each occurrence on the basis of these differences. The miscroscope has shown that, although of different appearance in the field, the mineralogical composition is practically the same, as also is the chemical composition. Hence, with one broad and rather arbitrary division separating the phonolites proper, and those of tinguaitic texture from those of trachytoid facies, the mineralogical and chemical characters of the different varieties will be described together, allusion being made to the separate occurrences only where some unusual feature seems to merit special mention.

Before attempting a description of these rocks, it would be well to briefly define the terms used for the different species.

The phonolitic rocks have been grouped under the following heads:

1. **Tinguaite.**
2. **Phonolite proper.**
3. **Trachytoid phonolite.**

Tinguaites.

Concerning the term **tinguaite** one cannot read the literature of the phonolites without feeling that considerable confusion has existed. Rosenbusch originally proposed the term for those rocks that formed the dike type of the nepheline-syenite series.

The type rock was dense, greenish and non-porphyritic, and consisted of an interlocking maze of ægirine needles with sanidine and some nepheline. Phonolite was the extrusive representative and consisted of a porphyritic rock with phenocrysts of sanidine and accessory ægirine in a groundmass of sanidine and automorphic nepheline.

Broegger, however, has used **tinguaite,** not only as a textural term, but to designate the basic members of his grorudite-tinguaite series. This usage is, therefore, partly chemical. There is, then, a two-fold division of the rocks, one on geological and the other on chemical characters.

In Broegger's use of the term the word represents a fairly definite group of rocks, and in that sense the more basic of the Black Hills phonolites are tinguaites. As regards the other or geological usage, the facts observed in the hills do not altogether justify its employment.

All of the rock types are here intrusive, and yet the texture in many cases differs in no essential degree from that observed in Rosenbusch's typical phonolites. Instances are, the rock from Ragged Top mountain, that from the sheet above Maurice, and the rock described by Caswell from Spearfish peak.

It is true that the texture known as tinguaitic occurs in almost all of the smaller dikes and masses of phonolitic rocks, but these are as frequently porphyritic as otherwise, the tinguaitic texture being confined to the groundmass. Phenocrysts of very large size often occur, some of them attaining the length of one inch. Instances are the dike near the Rua mine and the dike on the divide west of Twin Peaks and many others.

Again tinguaitic texture is not restricted to these smaller masses. Instances are rocks which make sheets of extremely large size. Such is the large mass northwest of the town of Englewood.

The name **tinguaite** has, therefore, been arbitrarily used in this paper to designate those rocks which possess a fine groundmass of interlocking needles of ægirine, with sanidine and more or less nepheline. Phenocrysts of sanidine and ægirine-augite may or may not be present.

Phonolites.

The phonolites proper are, as here described, those in which nepheline occurs in automorphic crystals, which may be readily distinguished by the microscope. They contain ægirine-augite, ægirine, orthoclase, nosean, and the accessories described below.

They differ from the tinguaite, into which they pass by imperceptible gradations, in the possession of much automorphic nepheline, and in not having so marked an interlocking series of smaller ægirines. On the other hand, they differ from the trachytoid varieties in the absence of the trachytic arrangement of feldspar in the groundmass, and in the possession of much nepheline. The transition in this direction is also gradual.

Trachytoid Phonolites.

These have prevalent orthoclase and little or no nepheline that can be identified without resort to gelatinization, and few of the fine crystals of ægirine that characterize the tinguaites and many of the phonolites proper. Much anorthoclase is probably present. The phenocrysts are large and the groundmass coarser than in the first two varieties. A trachytic flow structure of the feldspar of the groundmass is often observable. The rocks described from the Judith mountains by Weed and Pierson, as ægirite-syenite-porphyries are probably analogous to the coarser members of this series.

All three of these divisions are chemically similar, as will appear from the analyses on a later page, and the division is made more for convenience in petrographic description than for any other reason. For ordinary purposes the name phonolite is amply sufficient to cover the entire series.

Petrographic Description of Phonolite Family.

Megascopic Appearances.—The rocks of the phonolite family range in color from deep almost brilliant green to dark olive, grayish-green, dark bluish-gray, dove colored, light gray and almost white. The texture of the tinguaitic varieties is in some cases almost aphanitic as is notably that of the brilliant green variety from the hill to the southwest of Englewood. From this it becomes more porphyritic with both sanidines and ægirine minerals as phenocrysts. In relation to the groundmass the phenocrysts vary greatly in size and abundance, being now large and closely crowded, and again of small size and sparsely scattered through the rock. The phonolite described by Caswell from Black Butte, of which a specimen was collected and studied shows a dark brown color, with dark mottlings of a deep blue-green, giving it a singular poikilitic appearance totally different from that of any other phonolite in the region. It has, moreover, in an unusually marked degree the greasy lustre so frequently remarked in nepheline rocks, but which is completely lacking in many, if not most, of the phonolites collected by the writer, and which disappears altogether as we pass to the more trachytoid varieties. This peculiar lustre has been supposed to arise from the presence of nepheline, but, while the Black Butte phonolite in which it is most strongly marked contains a remarkable amount of this mineral, many of the more bluish varieties in which the microscope has shown great quantities do not exhibit it in the smallest degree. The dense tinguaitic varieties, however, show it frequently, and from this it seems probable that it arises from the presence of nepheline in the groundmass rather than from the crystals which may be identified by the microscope. If this be so it will be of great service in the determination of this mineral, for, unless observed in automorphic crystals it is practically impossible to establish its presence without resort to the test of gelatinization.

As we pass from the tinguaites and phonolites, into the phonolitic trachytes, we encounter a much lighter colored series of rocks, most of them being of a coarse porphyritic texture, and showing large crystals of sanidine of ½ inch and more in diameter. The groundmass frequently becomes inconspicuous, as in the rock from Raum's Drill and the "Spook" shaft near Balmoral (the peripheral phase of the Ragged Top mass) where the large phenocrysts are crowded so closely together as to comprise almost the whole body of the rock. The groundmass is, however, present, and in it are embedded large crystals of ægirine-augite, whose octagonal cross section is frequently to be marked without the aid of a glass.

These pyroxenes attain a size of ½ inch in length, and vary from that down to those just barely observable with the naked eye. The very fine microscopic ægirines that give the greenish color to the groundmass in the tinguaites are only sparingly present in the trachytoid varieties so that the groundmass of these rocks is prevailingly of a grayish to almost whitish tinge.

Microscopic Characters.—The microscope shows the following series of minerals: orthoclase (anorthoclase) microcline, pyroxene, nepheline, nosean, haüyne, biotite, magnetite, titanite, garnet (melanite variety) and a mineral formerly supposed to be leucite.

All of these minerals do not of course occur in the same specimen, but are found in the different varieties that comprise the series. Mention will be made under each mineral of the varieties in which it is most common, and when it occurs only in a single type a description of that rock will be included under the discussion of the mineral.

Orthoclase.—Although occasional crystals of albite occur in the groundmass of the more basic members of the series, the prevailing feldspar of these rocks is sanidine. Anorthoclase, while probably present in considerable abundance has nowhere been identified with certainty. The orthoclase occurs in large automorphic phenocrysts, and lath-shaped crystals, or xenomorphic grains in the groundmass. The phenocrysts are most frequently untwinned, showing the faces P, M, l and x, more rarely y; other faces were not observed. The phenocrysts contrast very markedly in habitat with those of many of the quartz-porphyries. The latter are prevailingly square in cross-section, showing as a rule only P and l.

Zeolitic alteration is quite often observed, and natrolite seems to be the most common product, although secondary quartz occurs quite frequently. In the majority of tinguaites the phenocrysts are small, being elongated parallel to *a* so that their length is often twice their breadth. They are scattered here and there, and attain a size of ¼ inch in length.

In two instances, however, they show a rather remarkably large development, namely, in the dike east of the Rua mine and in that northwest of the Twin peaks exposure. In the first-named rock they are thickly scattered through a dense dark-green groundmass and are oblong with a larger diameter often exceeding one inch.

These feldspars are unusually fresh and generally twinned after the Carlsbad Law. They are surrounded by a decomposed rim in many cases, but are never zonally built. In the rock from beyond the Twin peaks they are prevailingly larger and more elongated, especially near the contacts of the dike with the wall rocks. Resorption has generally been so slight as to leave the crystals quite sharp, but fracture has not infrequently occurred in such manner that the groundmass has been permitted to penetrate between the broken portions of the crystal.

As we pass from the phonolites to the trachytoid phonolites the groundmass becomes coarser and of a lighter hue.

The feldspar phenocrysts of the phonolites as a rule contain many inclusions; ægirine-augites, in short stumpy crystals, fine needles of ægirine that seem to be among the earliest formed ingredients of the rock; titanite and nosean. The ægirine needles are scattered through the feldspar sometimes in great abundance, so that, when viewed between crossed nicols, the darkened mineral is penetrated by a network of lighter lines made by the differently oriented needles of ægirine. This is especially noticeable in the rock from Raum's Drill. These needles are more thickly developed near the border of the crystal and frequently leave the cores quite clear. The included noseans are often large and almost as frequent in the feldspar as elsewhere in the groundmass.

The high percentage of soda in relation to potash in almost all of these rocks together with the investigations of L. V. Pirrson on rock from the Devil's Tower, in which the phenocrysts were found to be soda-orthoclase, have led the writer to believe that much of the feldspar in these rocks is of the same character. Many of the phenocrysts show a core of microcline which gradually shades into a clear, unstriated border of sanidine. Even the freshest sanidines show an exceedingly fine, longitudinal striation, which may perhaps be due to a very fine, almost sub-microscopic twinning arising from the triclinic character of the mineral.

The feldspars of the groundmass fall into two divisions: those which are long, lath-shaped and almost automorphic, and those which present an irregular jagged outline, and make up a groundmass almost granitoid in appearance. The former are characteristic chiefly of the trachytoid variety of phonolite. The rocks from Squaw Creek and Sugar Loaf Hill are good instances of this. The feldspars are sanidines, generally twinned, and with typical structure; sometimes entirely without definite orientation, impinging one upon the other in slightly irregular lines so as to form a hypidiomorphic texture. Quite frequently one may observe, scattered among them, laths of an acid plagioclase. The latter attains a maximum development in the more trachytoid varieties.

Interstitial masses of what seems to be nepheline are present in greater or less abundance, as also are recognizable crystals of this mineral, but they do not occur in as great abundance in the trachytic, as in the more granular groundmass.

Penetrating these feldspars in every direction are minute needles of ægirine which are present in great abundance in the tinguaites, but show a decreasing development as we approach the trachytes.

The other variety of feldspathic groundmass differs only in the degree of perfection of the constituent feldspars. It is best illustrated in the biotite phonolite from below Maurice (separately described on page 269) in which the feldspars do not show so strong a tendency toward automorphism as in many other of the rocks. In the tinguaites both the trachytic and hypidiomorphic types of groundmass occur.

Microcline.—Microcline is present sometimes as the core of the sanidine crystals previously mentioned, and again as distinct phenocrysts. The phonolite from the bottom of the Badger Shaft shows beautiful phenocrysts of microcline.

Ægerine-augite.—Soda-pyroxene is to be considered typical of these rocks, above any other mineral. It occurs in the most basic phonolites in great abundance, is a persistent feature up to the very most acidic types, and beyond these is still found in the very acidic quartz-ægirite-porphyries.

The pyroxene occurs in three distinctly separable varieties. *First:* Large automorphic crystals of ægirine-augite; *Second:* Smaller elongated needles of ægirine which have sometimes shredded extremities and sometimes abrupt crystal terminations and which are subsequent to the larger crystals in age of formation. They often occur as outer rims in parallel orientation with the latter. *Third:* Extremely fine needles of ægirine, long and sharp, but so very small in cross section that it is difficult to detect any pleochroism.

These have been briefly described under the quartz-ægirite-porphyries, but the more complete description is inserted here.

Pyroxenes of the First Variety.—The crystals of this group are prevailingly idiomorphic, the only modification being made by the addition of later deposited ægirines—crystals which are attached to the large cores, sometimes in parallel orientation and sometimes without definite arrangement.

The faces most commonly developed are ∞P (110) $\infty P \infty$ (100) and $\infty P \grave{\infty}$ (010). The tabular habit, ascribed to this mineral by Rosenbusch[1] through the development of the face $\infty P \grave{\infty}$ was often observed, but as frequently absent, for in sections perpendicular to the vertical axis the crystals are often square, or when flattened only slightly so. The other faces observed were $0P$ (001), and P (111). The face P (111) is rare, and has been identified but once with certainty. Determination of the axes of elasticity shows no variation from the usual type as described under the quartz-ægrite-porphyries.

An irregular zonal structure is almost always present. The cores of the crystals are slightly pleochroic or completely colorless augite. The ægirine molecule increases as we pass outward, and the whole is often surrounded by a deep green, highly pleochroic mantle of ægirine.

The different zones have decreasing extinction angles as we proceed from the center outwards until, in the ægirine mantle, they are practically zero. The ægirine and augite molecule vary greatly in their relations to one another. In the rock from the dike east of the Rua Mine the augite molecule is only sparingly developed, the large automorphic crystals being deeply colored and strongly pleochroic throughout, and possessing a low angle of extinction. In the tinguaite from Englewood, we have a green, quite strongly pleochroic ægirine-augite, with a very large extinction angle of 30 degrees, but only slight zonal development. From this we pass to the most common types in which zonal banding is more pronounced. Finally at the augite extreme we have in a phonolite from False Bottom Creek pyroxene crystals, which lack the ægirine molecule altogether. Others alongside of them are quite pleochroic, and still others, of almost colorless augite, have not only been surrounded by a thin mantle of ægirine, but have been invaded by the latter along lines of fracture.

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[1] Mikroskopische physiographie, Dritte Auflage, p. 538.

The pleochroism varies with the amount of the ægirine molecule present. In the larger and more perfect crystals, as in the fine tinguaite from Englewood, it is light pea-green parallel to $\mathfrak{c}$, also parallel to $\mathfrak{b}$; yellowish green, parallel to $\mathfrak{a}$. Absorption $\mathfrak{a} = \mathfrak{b} > \mathfrak{c}$.

Inclusions occur in great numbers in the ægirine-augites but with the exception of biotite and titanite, which are almost invariably found in the centers of the crystals, they are confined to the later-added border of ægirine. The shredded crystals rarely contain inclusions.

Pyroxene of the Second Variety.—From this more conspicuous variety of ægirine we may pass to that of a later generation, by very gradual degrees. This is invariably parallel in extinction and varies considerably in form. It has most often shredded extremities, but in many cases terminations can be seen. These are prevailingly 0*P* (001). It is more strongly developed in the tinguaites where it forms a reticulated, interlocked maze. As we pass toward the trachytoid varieties of phonolite, as in the rock from Raum's Drill, these smaller shredded ægirines give place to a much larger development of ægirine-augite, which is sometimes arranged in a seeming flow-structure around the phenocrysts. The smaller ægirines penetrate the groundmass in all directions, and are often included in the feldspar, and are arranged without orientation of any kind. When nepheline is present in automorphic crystals, it is formed earlier than these ægirines, for it occurs embedded in them or extends far into them from the border. In the rock described by Caswell from Black Butte, the ægirine forms interstitial masses like the augite in a diabase, the rôle of the feldspars being played by the nepheline. This is true also to a less extent in the phonolite from the Badger Shaft, and in that from the railroad cut at Maurice.

The pleochroism of the ægirine is very strong, and can be best observed when the crystals are large. It is blue-green to emerald green.

The Third Variety of Pyroxene.—The third division of ægirine is exceedingly interesting, as it is present in almost every type of the series from the rocks at the basic end to the exceedingly siliceous quartz-ægirite-porphyries. It comprises those fine hair-like needles that may properly be termed microlites. These needles penetrate the feldspar phenocrysts, the quartz in the quartz-ægirite-porphyries, and the feldspar of the groundmass. They are not, however, found as inclusions in the large ægirines, in the nepheline or the nosean and titanites, nor do they ever form parallel growths with the larger crystals. Hence it can be inferred that their period of formation followed that of the larger ægirines, and preceded the period of the feldspar phenocrysts.

Nepheline.—This mineral occurs as idiomorphic crystals in the majority of the tinguaites. It reaches the highest degree of development in the phonolites proper, and in the trachytoid varieties occurs only as interstitial masses.

In the phonolite from Spearfish Peak (Black Butte) it has attained a remarkable perfection. Sections show hexagonal cross-sections, dark during the rotation of the stage and square sections with parallel extinction and low single and double refraction. An analysis of the rock will undoubtedly show a remarkable amount of soda. The crystals show great numbers of inclusions, most of them highly refractive, but too small for determination. For this rock Caswell[1] gives:

SiO_2, 56.32 %; soluble in HCl with very strong gelatinization, 24.08 %; which shows how large is the percentage of nepheline. Again in the rock above Maurice the nephelines are in great abundance. The rock is different from that from Black Butte in its bluish color, its almost complete lack of greasy lustre, and the presence of macroscopic sanidine phenocrysts. Under the microscope also it shows the ægirine in bundles and shredded crystals instead of the irregular masses characteristic of the Black Butte rock. Nosean is also abundant. The nepheline, however, except that the crystals are smaller, bears the same relations to the ægirines and feldspar of the rock.

The rock from the bottom of Badger Shaft exactly resembles that from Maurice, except that the nephelines are larger, and more abundant.

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[1] Rep. Geol. and Resources of the Black Hills of Dakota. U. S. G. G. Survey. 1880. p 526.

In the tinguaites automorphic nepheline occurs less abundantly, and frequently cannot be detected at all. The presence of nepheline, however, seems to be proved by the gelatinization of the pulverized rock, as also by the analysis.

In the trachytoid phonolites nepheline occurs only occasionally in automorphic crystals, but gelatinization seems to indicate that it occurs interstitially in the groundmass. A slide, when treated with hydrochloric acid and stained with fuchsine, showed irregular masses of gelatinized mineral, irregularly placed among the feldspars.

Nosean.—This occurs in great abundance in the phonolites proper and to a slightly lesser degree in the tinguaites. It seems to accompany the nepheline to a large extent, being present in the greatest abundance in those rocks containing the most of that mineral. It occurs in large dusty hexagonal sections mostly showing a clear border. Sometimes several crystals will be grouped together in parallel growth. It antedates the feldspar phenocrysts in the age of its formation. It contains inclusions of ægirine in great numbers, but always small and irregular. They seem to have a slightly green tinge, and are identical with a mass of little kernels of the same mineral grouped against the sides of the crystal, and apparently excluded from it during the process of crystallization.

The nosean is always automorphic, and occurs as frequently embedded in the phenocrysts of feldspar as in the groundmass. It is often found partially included in the phenocrysts and partially in the groundmass without. In the trachytoid phonolites, nosean is absent.

Haüyne.—This was found only in a single instance, and then in very small although beautifully developed crystals. The rock in which it occurs is an extremely fine grained variety of phonolite, and was collected from a mass of irregular form, near the mouth of one of the northeastwardly draining tributaries of Squaw Creek. This Gulch is the second to the west of Labrador Gulch.

Biotite.—This mineral is present in the more trachytoid varieties of phonolite as occasional dark flakes and may also be observed in the tinguaites. One variety of trachytoid phonolite deserves special mention. It occurs as a sill in the Cambrian shales about half a mile below Maurice in Spearfish Cañon. The rock is light gray, has a greasy lustre, and can be seen to contain innumerable flakes of biotite. Some of them attain a diameter of three-eighths of an inch. The microscope shows the rock to consist of an almost granular aggregate of twinned feldspars amongst which an occasional nepheline can be detected. Through this mass are scattered shredded crystals of ægirine, the usual larger crystals of ægirine-augite and numerous irregular crystals of biotite.

The biotite is in deep red-brown flakes, and is very pleochroic. Around it is grouped in a thick felt-like mass, often equal in diameter to one-half the width of biotite, a maze of ægirine microlites. Mixed in with these are longer, shredded ægirines, and an occasional terminated crystal. Besides the biotite and also surrounded by a coating of irregularly piled microlites are masses and hexagonal cross-sections of an isotropic mineral. It is filled with minute dusty inclusions of unknown character, and with crystals of ægirine, and is perforated through and through by long needles of the same mineral. It is absolutely isotropic, showing not the slightest indication of cross twinning and when viewed between crossed nicols letting no light through, except where doubly refracting inclusions are present. It is generally hexagonal in outline, but occurs also in irregular blotches. It is identical with the isotropic mineral discussed under leucite.

Magnetite.—Magnetite occurs but sparingly in the phonolite-trachyte series. It is, however, seen in the phonolites from Maurice and Ragged Top, in considerable quantities. In the latter rock it occurs in irregular masses, with characteristic color and lustre.

Titanite.—Titanite occurs, as an almost invariable accessory in nearly all of the rocks of this series. It is generally in long, tabular, lath shaped crystals and exhibits the usual high relief and cleavage. It is often included in the ægirine-augite, and feldspar phenocrysts. The crystals are frequently twinned.

Garnet (*Melanite*).—In the phonolite from the summit of Ragged Top Mountain, masses of this mineral can be observed. It is dark brown, with irregular fracture and high relief, and between crossed nicols shows faint double refraction. It is surrounded by a dark mass consisting of interlocking crystals of ægirine and ægirine-augite mingled with magnetite grains and an undetermined decomposition product.

Leucite (?).—In 1897 a series of rocks from the Black Hills was sent to Professor Kemp by Professor F. C. Smith, of the Rapid City School of Mines, and determinations were made by Mr. D. H. Newland in the laboratory of Columbia University. Among these rocks were a set which were determined as leucitophyres and leucite-phonolites, and were described as such by Professor Smith in his paper on the "Potsdam Gold Ores of South Dakota."[1] It was also on the basis of these determinations that the statement was made by Professor Kemp, in a paper on the leucite hills of Wyoming, that leucite rocks were abundant in the Black Hills. Since then further investigation seems to show that this mineral may prove to be one of the sodalite group, or at least that its determination as leucite is somewhat questionable.

The most perfect instance of a rock of this kind is that occurring in a thick sheet at the mouth of Anne Creek, where it enters Spearfish Cañon. A similar rock was found in a shaft northwest of Carbonate. The other leucite rocks occur in a mass on the divide to the south of Ragged Top, on Green Mountain, and on the edge of the limestone bluff opposite Little Spearfish Falls. In addition to these, the writer has found a great many occurrences showing the same isotropic mineral in greater or less abundance.

In microscopic appearance, the rocks containing this mineral do not differ from those of the phonolite series, but show the same variations from a dense texture and dark green color to lighter gray and more coarse-grained rocks. The rock from Annie Creek shows the typical dense texture and green color of a tinguaite. The phenocrysts are small and inconspicuous, and not present in great abundance. The specimens selected for study were obtained from the freshest portion of the rock, and showed little or no decomposition. Under the microscope the rock is seen to be composed of a fine mesh of ægirine needles, between which are hexagonal, slightly rounded and irregular masses of an isotropic mineral, which, with subordinate rods of orthoclase, makes up the body of the rock. The hexagonal form predominates, but occasional square sections are observed. Octagonal sections were not observed. Sanidine phenocrysts are sparingly distributed, and when seen are zonally banded, and contain hexagons and squares of the same isotropic mineral.

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[1] Trans. Am. Inst. Mining Engineers, Vol. XXVII, p. 411, July, 1897.

The isotropic mineral remains almost completely dark during the rotation of the stage, no light penetrating it except when doubly refracting inclusions are present.

Not the faintest trace of twin lamellation was observed by means of the gypsum plate, even in the larger crystals. As a rule, innumerable dusty inclusions can be observed, but these may sink in prominence until the mineral is almost clear. The inclusions are almost without exception ægirine. Slides were treated with hydrochloric acid and then stained with fuchsine, the result being a strong gelatinization which seems to be almost wholly confined to the isotropic mineral.

A glance at the analysis No. XV when compared with those of the other phonolites shows that there is no increase in the proportion of soda as compared with the potash, although such has been shown not to be essential to the formation of leucite. Still, one would hardly expect so high a percentage of soda where so little nepheline and so much leucite are present. Again such marked gelatinization seems to bar out such an interpretation, and the fact that the mineral occurs included in the feldspar phenocrysts would seem sufficient to exclude the possibility of analcite, which in rocks of this kind is a secondary mineral. We are then forced to consider the sodalite group as the only explanation.

Nosean occurs with such frequency in these rocks and is so often without the prominent border, that in small crystals a confusion with leucite might readily occur.

In a description of the rock from the Mato Tepee, Pirrson mentions the occurrence of a mineral similar to that here described. "There appear also small hexagonal sections of a mineral which is full of dusty inclusions, and always isotropic. It is supposed to be of the sodalite group, which is also indicated by the chlorine shown in the analysis."[1]

Without a complete chemical analysis of the separate occurrences and a much closer study of the material than it has been possible to make in the preparation of this paper, the writer would hesitate to pronounce this nosean, thus making a separate division of noseanophryes. The rocks in which it occurs have therefore been classed with the phonolites, which they resemble in all other respects.

ANALYSES OF PHONOLITES.

	I	*II*	*III*	*IV*	*V*	*VI*	*VII*	*VIII*	*IX*	*X*
SiO_2	56.940	55.62	59.230	58.560	58.580	58.940	58.980	59.250	56.340	58.65
Al_2O_3	21.031	20.458	21.098	18.142	17.190	18.111	16.032	19.460	21.057	16.45
Fe_2O_3										4.08
FeO	3.408	4.060	4.132	7.324	7.686	6.308	8.265	5.076	4.205	
CaO	1.930	1.910	0.640	1.560	0.880	0.570	1.110	2.070	3.340	3.78
MgO	0.327	0.616	0.472		none	trace	trace	trace	0.709	trace
K_2O	4.657	4.384	4.486	5.278	4.536	6.872	4.898	3 961	4.082	4.16
Na_2O	9.046	7.640	8.670	8.492	9.261	7.564	8.280	7.391	9.274	8.92
H_2O	0.390	0.570	0.100	0.120	0.090	0.090	0.510	0.700	0.070	0.29
Loss.	2.150	4.220	1.180	1.010	1.650	1.360	2.070	2.120	0.900	2.78
Total.	99.879	99.478	100.008	100.486	99.773	99.815	100.145	100.028	99 977	99.11

	XI	*XII*	*XIII*	*XIV*	*XV*	*XVI*	*XVII*	*XVIII*	*XIX*	*XX*
SiO_2	61.08	55.60	55 940	57.880	56.570	58.090	58.380	57.210	57.450	58.590
Al_2O_3	18.71	19.705	20.905	20.461	20.736	21.288	20.395	18.673	20.376	20.766
Fe_2O_3	1.91									
FeO	0.63	5.494	4.495	3.770	5.656	4.061	4 423	3.408	3 630	4.350
CaO	1.58	1.690	1.730	0.760	1.050	0.810	1.560	3.070	1.840	1.460
MgO	0.08	0.861	0.421	0.281	0 234	trace	trace	1.099	trace	0.464
K_2O	4.63	4.881	5.441	5.112	4.487	3.794	6.261	4.916	6.186	4.803
Na_2O	8.68	8 604	8.866	8.738	9.358	9.345	6.234	6.622	7.412	8.170
H_2O		0.340	0.310	0.170	1.110	0.200	0.500	1.010	0.360	0.090
Loss.	2.21	2.890	2.430	2.550	1.490	2.260	2.700	3.610	2.760	0.920
Total.		100.065	100.538	99.722	99.691	99.848	100.453	99.618	100.014	99.613

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[1] L. V. Pirrson, *Am. Journal of Science*, May, 1894, Vol. XL, VII, page 344.

Chemical Composition of the Phonolites.

In their chemical composition the phonolites vary only within narrow limits.

On page 272 will be found a series of analyses.

Phonolites.

I. Phonolite from the summit of Ragged Top Mountain. Contains nepheline, orthoclase, ægirine, magnetite and melanite garnet. This rock is a typical phonolite. Analysis by Professor F. C. Smith, Deadwood, South Dakota.

Tinguaites.

II. Tinguaite from dike on Ulster claim of A. J. Smith, near Preston, South Dakota. Analysis by Professor Flintermann, Deadwood, South Dakota.

III. Tinguaite.—Dike in Squaw Creek, below Gushurst mine. Typical tinguaitic texture. Analysis by Professor Flintermann, Deadwood, South Dakota.

Trachytoid Phonolites.

With Tinguaitic Aspect.

IV. From the sheet at the junction of Annie and Rose Spring creeks. Analysis by Professor Flintermann, Deadwood, South Dakota.

V. Rather fine-grained variety from sheet in Annie Creek, near loop of Burlington and Missouri River Railroad. Analysis by Professor Flintermann, Deadwood, South Dakota.

VI. Trachytoid phonolite from Annie Creek near Loop on the Burlington and Missouri River Railroad. Analysis by Professor Flintermann, of Deadwood, South Dakota.

VII. From same locality as No. *VII.* Professor Flintermann, analyst.

VIII. Sheet near last. Analysis by Professor Flintermann,

Trachytoid Phonolite.

IX. Large sheet in Squaw Creek. Specimens taken from the dike-like portion forming the "Gateway." Analysis by Professor Flintermann, of Deadwood, South Dakota.

X. Very coarse trachytoid phonolite from "Raum's Drill," in the bed of Calamity Gulch. Analysis by J. D. Irving.

XI. Rock from the Mato Tepee or Devil's Tower. L. V. Pirrson, *American Journal of Science,* Vol. XL, VII, p. 344.

XII. Rock from Annie Creek, cut on the Burlington and Missouri River Railroad. Analysis by Professor Flintermann, of Deadwood, South Dakota.

XIII. Rock from lower cut on the Burlington and Missouri River Railroad, near mouth of Annie Creek. Analysis by Professor Flintermann, of Deadwood, South Dakota.

XIV. Rock from irregular mass in the limestone to the South of Calamity Gulch, and west of Elk Mountain. Analysis by Professor Flintermann, of Deadwood, South Dakota.

XV. Rock from thick sheet n the mouth of Annie Creek. This rock has the typical texture of a tinguaite, and contains some nepheline with much nosean and sanidine. There is also in very great abundance of the isotropic mineral at first supposed to be leucite. Analysis by Professor Flintermann, of Deadwood, South Dakota.

XVI. Rock from the summit of Green Mountain. This is a phonolite o trachytoid character, but possesses the typical tinguaitic groundmass. In addition to this there is present much of the same isotropic mineral referred to above.

XVII. Loose fragments from Annie Creek. Determined as leucitophyre by Mr. D. H. Newland. Analysis by Professor Flintermann, of Deadwood, South Dakota.

XVIII.[1] Phonolite dike from Whitetail crossing in Whitetail Gulch. Analysis by Professor Flintermann, of Deadwood, South Dakota.

XIX.[1] Rock from sheet in Whitetail Gulch below Sugar Loaf Hill. Analysis by Professor Flintermann, of Deadwood, South Dakota.

XX. [1] Phonolite from the East Slope of Bald Mountain. The exposure from which this was taken is probably a dike. Analysis by Professor Flintermann, of Deadwood, South Dakota.

If we run over these analyses, it will at once appear that the phonolites are of a remarkably uniform composition.

The Rock from Ragged Top Mountain, which is a typical phonolite with much nepheline, shows little if any difference, from the more trachytoid varieties, in which very little of that mineral is present. The inference is that since the ratio of soda to potash remains unaltered, much of the former has contributed to the formation of anorthoclase feldspar. That this is true in the case of the rock from the Mato Tepee has been shown by L. V. Pirrson.[2]

The rocks showing tinguaitic texture do not differ in chemical composition from the rest of the phonolites.

The rocks in which leucite is supposed to occur show little if any difference from the rest of the series. In one instance, however, No. *XVII*, the amount of potash rises to six per cent. and the soda is proportionately diminished. This rock has more the appearance of a leucite rock than any of the others.

The complete investigation of these supposed leucite rocks is reserved for a future paper.

3. Rhyolite Family.

The rocks belonging to this family show a considerable variation in texture and appearance, but are easily separated from the phonolites. They are usually very much more decomposed than the latter, and seldom show dark silicates in an undecomposed condition. They are very extensively developed, and nearly equal the phonolites in the extent of the area they cover.

They will be described under the following types:

1. Portland Type.
2. War Eagle Hill Type.

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[1] Rocks Nos. *XVIII*, *XIX* and *XX* were not examined by the writer but determined by Mr. D. H. Newland in the laboratory of Columbia University.

[2] *American Journal of Science*, May, 1894, p. 344.

3. Foley Peak Type.
4. Nevada Gulch Type.
5. Whitetail Gulch Type.

Portland Type.

At the head of Squaw Creek, near the old Portland mill, occurs a very thick sheet of quartz-porphyry.

Megascopic Character.—It is a reddish brown rock, much decomposed, and only in rare instances shows macroscopic crystals of quartz. The groundmass is brown in color and exceedingly dense, containing occasional flakes of biotite. The feldspars are of uniform size, averaging about a fourth inch in diameter, and are so much resorbed that they often show a somewhat lenticular aspect, which has given rise to the local name of " Bird's Eye " porphyry.

Microscopic Characters.—Under the microscope the rock is seen to consist of phenocrysts of sanidine and plagioclase embedded in a groundmass of very fine xenomorphic grains of quartz and orthoclase.

The sanidines are somewhat resorbed and are prevailingly twinned after the Carlsbad Law. They far exceed the plagioclase crystals, both in size and number, but the latter attain a somewhat unusual development for a typical rhyolite. Phenocrysts of microcline are also of frequent occurrence. Biotite is scattered through the groundmass in quite conspicuous masses. The rock is one of the typical quartz porphyries, but is usually taken for trachyte, as the quartz is not apparent to the eye. It differs from the other quartz porphyries in the absence of microscopic quartz, and the rounded character of the phenocrysts.

CHEMICAL COMPOSITION.

	I.	*II.*
SiO_2	69.78	67.77
Al_2O_3	16.07	17.57
Fe_2O_3	2.47	....
FeO	Not det.	1.59
CaO	1.17	0.51
MgO	trace	0.49
K_2O	Not det.	4.56
Na_2O	Not det.	6.20
H_2O	0.65	0.73
Loss	0.10	1.47
		100.89

I. Quartz-porphyry known as "Bird's Eye porphyry" from sheet along the Burlington and Missouri Railroad on Crown Hill. Analysis by J. D. Irving.

II. Quartz-porphyry from large dike in the Ulster Mine, near Preston, South Dakota. This rock forms the wall of the ore deposits and is cut by a phonolite dike. The ore is associated with the phonolite, and is stained with purple fluorite. Analysis by Professor Flintermann, of Deadwood, South Dakota.

In both of these rocks lime is very low, considering the very considerable amount of plagioclase that is present. The percentage of soda is, however, so high that we would infer that the plagioclase is quite probably an albite, which is also shown by measurements on albite lamellæ.

War Eagle Hill Type.

Further down the valley of Squaw Creek, and forming the main mass of War Eagle Hill, occurs an exceedingly dense, dark quartz porphyry, which apparently intersects the lighter variety.

Megascopic Appearance.—This rock has a grayish color, and shows frequent phenocrysts of orthoclase. These are embedded in a dense bluish groundmass, in which smaller feldspars may be easily distinguished. Macroscopic quartz is frequently present. The rock has many inclusions of all descriptions, the commonest being slate fragments, and the most interesting, masses of a coarse-grained binary granite.

Microscopic Characters.—The microscope shows the rock to consist of a groundmass of quartz and feldspar. In this are embedded innumerable sanidine phenocrysts of varying size and form. Most of them are but little resorbed, and the larger number are square in outline showing only *P* and *l*. A marked zonary banding is generally present.

A considerable number of the feldspar phenocrysts are microcline and an acid plagioclase, which is probably albite. In many cases the albite occurs included in the sanidine phenocrysts. Much pyrite is present, and is sometimes seen lining the edges of myarolitic cavities, in which are confined sulphurous gases, so that the rock when broken exhales an extremely offensive odor.

Foley Peak Type.

Upon Foley Peak occurs a quartz-porphyry, which shows a much coarser groundmass than that occurring on War Eagle Hill. It is composed o a xenomorphic aggregate of quartz and orthoclase in quite large masses. In this are phenocrysts of quartz and plagioclase, the former being the most abundant.

In certain portions of the mass this rock shows large and quite numerous phenocrysts of quartz in addition to that present in the groundmass. Otherwise it differs little from the War Eagle Hill type except in the coarseness of the groundmass.

Nevada Gulch Type.

This type of quartz-porphyry occurs in a dike along the road just below the junction of Nevada and Fantail Gulches.

Megascopic Appearance.—The rock is of a light gray, porphyritic character. The groundmass is dark gray, and very fine grained, but is so thickly crowded with small phenocrysts of feldspar that it will not be at first noticed. Quartz phenocrysts also occur in abundance, and sometimes attain a size of one-half of an inch in diameter, although most of them are smaller. Besides these phenocrysts of quartz and feldspar, which range about one-eighth inch in diameter, extremely large crystals of sanidine of an older generation occur in such an abundance as to give the rock almost the appearance of a granite-porphyry. The latter crystals range from three-eighths of an inch to one and one-half inches in length. They are invariably idiomorphic, are always undecomposed and never show corroded boundaries. Scattered through the groundmass are minute flakes of biotite.

Microscopic Characters.—Examined microscopically, the rock shows an exceedingly fine-grained, granular groundmass, made up of quartz and feldspar, in which are embedded decomposed plates of biotite, quartz phenocrysts and alkali feldspar of two generations. The biotite is much decomposed. The quartz is in automorphic crystals, and much corroded, and contains numbers of inclusions. The most abundant of these are little bubbles of gas, and irregular patches of a mineral, with a very high index of refraction, but whose nature was not determined. The smaller feldspars are present in great numbers, and are almost invariably decomposed. Many of them are an acid plagioclase, probably albite.

The larger phenocrysts are sanidine, very fresh and most frequently in Carlsbad twins. They contain great numbers of inclusions, which can be seen in roughly zonal arrangement, even in the hand specimen. Most important of these are quartz and feldspar. The inclusions of quartz are often so large as to be in the nature of true phenocrysts, when considered in relation to the body of the rock. The feldspar inclusions are both orthoclase and albite.

Whitetail Gulch Type.

Still another type of quartz-porphyry occurs on the Black Hills and Fort Pierre Railroad, in Whitetail Gulch, a little north of the mouth of Fantail and Nevada Gulches.

Megascopic Appearance.—It is of a dark bluish gray color, grading to whitish gray in the more coarsely grained portions. It occurs also in other localities in considerable abundance.

Microscopic Characters.—The microscope shows the following minerals: orthoclase, plagioclase, quartz, biotite, chlorite and magnetite.

The groundmass is extremely fine, as in the last rock described, but is markedly granular in texture. In it are embedded in about equal numbers, phenocrysts of sanidine and plagioclase both of which are in an advanced stage of decay. The biotite is in quite noticeable and thickly disseminated flakes, and generally shows a twisted appearance as if disturbed by the flow of the rock. Chlorite and magnetite are also present, the former as a decomposition product of biotite, and the latter in irregular grains.

The quartz contains inclusions of zircon, and is in the usual resorbed crystals. It also shows an extraordinary amount of fracture, which has evidently been caused by the flow of magma. The fractured portions of the phenocrysts are scattered all through the groundmass, and are of all sizes, giving the rock at first sight the appearance of a breccia.

The broken edges are generally extremely sharp and angular and only occasionally show a contour rounded by corrosion.

From the condition of the quartz it is to be inferred:

1. That the crystallization of the quartz phenocrysts took place before the forces which produced the upward flow were operative.

2. That the quartz crystals were broken by the flow of the magma during its intrusion.

Other than the broken quartz crystals, this rock shows marked evidences of flow. They can best be observed in the field. The rock consists of two portions, a granular, white and rather coarse-grained rock of porphyritic texture, and a much darker, at times completely aphantic, material arranged in flow lines or *schlieren.* The two are mingled together in just such eddies and swirls as are seen in a pot of paint where two colors are mixed together. At one point a large mass of amphibolite is included and around it the flow lines make a series of fantastic curves and eddies, following the contour of the included fragment. The separate layers are of all thicknesses, but are so sharply marked off from one another that they may be readily followed. Many of them thin out into mere hairlike tongues, which may still, however, be distinguished from the adjacent layers by their sharply contrasted color. Under the microscope these different layers show simply a difference in the texture of the groundmass, and in the abundance of phenocrysts, the latter occurring at much rarer intervals in the darker and more fine-grained streaks. A photograph showing these flow lines may be seen in Plate XVI.

4. Andesite Family.

Mica-Diorite-Poryhyry.

This rock occurs in quite large development throughout the region of Squaw Creek, and in the Ruby Basin. In the head of that creek, in the upper shaft of the Rua Mine is a sheet, and the same rock forms the large Redpath laccolite. It occurs also in irregular masses in Squaw Creek and its tributaries, and forms a sheet of considerable size at the mouth of that creek. There is further a large development in the vicinity of Carbonate Camp.

The analyzed specimen is from the Rua Mine, and when seen in hand specimens, it presents a very much darker and more basic appearance than any of the rocks so far described.

Megascopic Appearance.—It has a dense bluish black groundmass, in which are thickly disseminated small scales of biotite. and when in the fresh condition large prisms of hornblende, giving to the rock a very basic aspect. In the rock from the flat northwest of Twin Peaks the hornblendes are present in great development, but in the other occurrences are generally decomposed and show only chloritic pseudomorphs. The feldspar phenocrysts are not in very great abundance and often show an almond-shaped cross-section, rarely attaining a greater length than one-fourth inch. When the rock is much altered the biotite seems to have been one of the most resistant minerals, and remains protruding in glittering flakes, which gives to the weathered specimens a very basic appearance.

Microscopic Characters.—The microscope shows the following minerals: plagioclase, orthoclase, biotite and hornblende or chlorite, as phenocrysts; plagioclase, magnetite, chlorite, calcite and quartz in the groundmass. The plagioclase phenocrysts show the usual polysynthetic twinning. They are generally fairly fresh in the central portions, but are somewhat decomposed along their borders. Measurements made in sections on the zone perpendicular to *M* showed maximum extinction angles of 23 degrees. This would place the feldspar among the oligoclase-andesines.

The orthoclase phenocrysts vary in abundance, but are always subordinate to the plagioclase.

In the rock from the gulch west of Labrador, orthoclase is entirely absent, both as phenocrysts and in the groundmass. In that from the Rua Mine it appears as occasional phenocrysts, and from the Redpath Creek laccolite it equals the plagioclase in amount. The biotite is in hexagonal and rectangular flakes and usually quite fresh. It has a strong pleochroism, opaque brown, parallel to the cleavage, and greenish brown at right angles to it. The absorption is much stronger in the larger and fresher masses. In those which show a slightly decomposed border it is colorless parallel to the cleavage, and light yellow at right angles to it.

The hornblende was observed in a fresh condition in only one specimen, that from the flat northwest of Twin Peaks. Here it occurs in large crystals with blunt terminations, showing cross sections ¼ × ⅜ inches in maximum development. The crystals are short and thick set, never acicular, and show the usual cleavage characteristic of the mineral. They have the faces $\infty P \grave{\infty}$ (010), ∞P (110) in strong development, and are terminated by the usual $P \grave{\infty}$ (011). No other faces were observed Maximum extinction angles range about 12° to 15°.

The pleochroism is:

Deep olive green $\parallel \mathfrak{c}$.
Faint yellowish green $\parallel$ to $\mathfrak{c}$.
“ “ “ $\parallel$ to $\mathfrak{b}$.
Absorption $\mathfrak{c} > \mathfrak{b} > \mathfrak{a}$.

The chlorite, which occurs as large masses, has resulted from the decomposition of the hornblende, being prevailingly pseudomorphic after that mineral.

The groundmass is composed of irregularly bounded, lath-shaped masses of striated feldspar, some undoubted orthoclase, and an abundance of magnetite in grains and irregular masses. Chlorite, calcite and secondary quartz are present as alteration products. The following is a partial analysis of the rock from the Rua mine:

SiO_2	55.26
Al_2O_3	17.67
Fe_2O_3	5.39
CaO	5.26
MgO	3.21
K_2O	not det.
Na_2O	not det.
loss	4.53
H_2O	.45

Two other occurrences of the rock are worthy of note. One is in the town of Terry in a thick sheet of considerable development, which is also exposed on both sides of Fantail Gulch along the railroad. The rock is here much finer grained than that described, and is almost granular. The crystals of hornblende are much more widely disseminated through the rock, although somewhat smaller, and in all cases altered to chlorite. Biotite is less abundant. Garnet sometimes occurs; otherwise the rock shows no difference from the usual type.

The other occurrence of diorite-porphyry is very important. It is on the west of Spearfish Creek in the up-lift known as the Needles (see p. 224). It is a highly porphyritic rock, with even-tinted light-gray groundmass, in which are embedded white phenocrysts of feldspar and abundant glittering blades of hornblende. No biotite is present, and the rock is of a very much less basic type than the others described. The microscope shows a fine-grained ground mass of irregular masses of plagioclase, amongst which a few rectangular crystals of orthoclase occasionally appear, and through which grains of magnetite are thickly scattered. The phenocrysts are plagioclase and sanidine in almost equal development, and hornblende, which is always in automorphic crystals. The plagioclase and hornblende show no unusual features and the chief point of interest about the rock is that its affinities to the andesites and trachytes are about equally divided.

5. Dacite Family.

Of this family two types are described: 1st. Crow Peak Type. 2d. Deadwood Gulch Type.

Crow Peak Type.

The first rock determined by the writer under this name, was taken from the summit of Crow Peak. It was described by Caswell[1] as rhyolite as follows:

"The rock (141 and 142) from Crow Peak is a rhyolite, containing plagioclase, and is much more crystalline than the preceding, having microscopical sanidine crystals plainly embedded in a groundmass. They are white and very transparent. There are also some black crystals of hornblende and empty cavities, which were formerly filled with the mineral. In the section, the microscope shows the rock to consist of large, clear crystals of sanidine and plagioclase in a crystalline groundmass, also containing broken biotite crystals and some quartz in grains and crystals."

In the section examined by the writer all of these minerals were observed, but a few additional important features need to be emphasized. The phenocrysts, with the exception of one or two crystals, are all plagioclase, and the few sanidines present are smaller than the plagioclases. Plagioclase was not observed as a core, although apparent crystals of sanidine were observed with fragments of striated feldspar attached to them in different orientation. It is probable that many of the sanidines described by Caswell were merely plagioclase, cut parallel to the twinning lamellæ. Measurement of extinction angles on sections cut perpendicular to albite lamellæ give a maximum angle of 18 degrees, which places the feldspar among the oligoclase andesines.

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[1] Report of the Geol. and Resources of the Black Hills. U. S. G. G. Survey, p. 506.

The groundmass is composed of great numbers of automorphic sanidines of considerable size. They are prevailingly square in section and are accompanied by other interstitial masses, not so perfectly developed. Quartz has only attained a slight development, although quite a few grains of this mineral seem to be present, giving higher colors than the gray feldspar. None of them are large enough to give an axial cross. The silica determination published by Caswell, 67.36 per cent., places the rock at the upper limits of andesites series and makes the presence of considerable quartz probable.

Quite a prominent accessory of the rock is titanite, which forms crystals of considerable size.

Deadwood Gulch Type.

From the Crow Peak rock we may easily pass to another rock which differs but little from it in general appearance, but is very much more acidic. This rock occurs in a very large dike on the loop of the Fremont, Elkhorn and Missouri Valley Railroad. Macroscopically, it is a very light, whitish gray, porphyritic rock, with numerous irregularly bounded, and often very large phenocrysts of quartz.

The feldspars are prevailingly small, rarely attaining the diameter of a fourth inch. Most of them are from four to five millimeters in breath. The groundmass has a dense light gray appearance, and is sharply contrasted with all the rocks yet described in containing few if any ferruginous minerals.

Under the microscope the rock is seen to be made up of a very fine-grained granular groundmass, which is probably feldspathic. In this are embedded phenocrysts, of plagioclase and quartz, with occasional sanidines. The groundmass contains scattered grains of magnetite.

The plagioclases show an extinction angle on albite lamellæ of 18 to 20 degrees, which show them to be of quite a basic type. They are sometimes seen in parallel growth with sanidine. In the only large sanidine crystal seen in the slide, a complete crystal of plagioclase was included. (Fig. 14.)

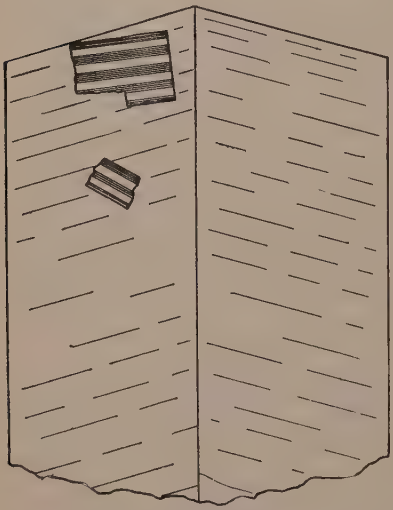


FIG. 14.

Plagioclase included in sanidine from quartz-ægerite-porphyry from sheet on Burlington and Missouri River Railroad, near Terry Station.

The quartz is in extremely large crystals, and abounds in inclusions. It is resorbed to a remarkable degree, the groundmass encroaching on it in unusually deep bottle-shaped *embayments*.

It is very much fractured, and frequently in long crystals that have a far greater length than breadth.

6. Diorite Family.

Tonalite (Quartz-mica-hornblende-diorite).—This rock is exposed in the cut of the Fremont, Elkhorn and Missouri Valley Railroad in Deadwood Gulch, some little distance west of Go-to-Hell Gulch, and is in an exceedingly thick dike in the Algonkian formation.

Megascopic Characters.—The rock is gray, granular-looking and of an even texture, the constituent minerals being of such size as to be easily recognized without the aid of the microscope. Basic segregrations and angular inclusions of a basic character are very numerous.

Microscopic Characters.—Under the microscope we may recognize the following minerals: plagioclase, quartz, orthoclase, biotite and hornblende. These are arranged in granular texture, being largely without crystal boundaries. There is, however, a slight tendency toward an automorphic development in the feldspar, such as would be anticipated in a rock of this character. That we have here a rock of so nearly granitoid texture is undoubtedly due to the very large size of the intruded mass.

The plagioclase slightly outranks the orthoclase in abundance. Maximum extinction angles measured on albite lamellæ did not give very satisfactory results, but the mineral seems to be of quite an acid type. The other minerals present no unusual features.

7. Lamprophyre Family.

Augite-Vogesite.

This rock was found cutting the diorite-porphyry of the needles uplift in Bear Gulch on the west of Spearfish Creek.

Megascopic Characters.—It is a dense, black rock, carrying no noticeable phenocrysts, and of extremely fine grain.

Microscopic Characters.—The microscope reveals the presence of the following minerals: augite, hornblende, magnetite and feldspar. The augite constitutes the main body of the rock, and is always in automorphic crystals. These are small and usually free from inclusions, but exhibit the characteristic cross-section, and cleavage of the mineral.

Hornblende is present in long needles, but compared to the augite, is sparingly developed.

Between the crystals of augite and hornblende, occurs a small amount of glassy groundmass, in which from time to time, singly twinned feldspar may be observed. The feldspar is probably orthoclase. From these facts, and from the almost perfect panidiomorphic texture of the rock, it has been classed with the vogesites. It exactly parallels the camptonites which are so often associated with elæolite syenite magmas, except that the component mineral is augite, instead of the usual brown basaltic hornblende.

It is to be regarded as the final and most basic segregation of the highly alkaline magma, whlch has produced the phonolite series.

8. Amphibolites.

Under this head are classed together a large and varied group of rocks whose chief constituent is a secondary hornblende, or uralite. This can in some cases be traced back to an original pyroxene, but at times the alteration has been complete, and we have no means of determining the origin of the mineral.

The amphibolites occur in dikes of varying width between walls of Algonkian slates and schists. Whenever they are very wide, the center is an unaltered core of very homogeneous character. Increasing schistosity can then be traced outwards, till the rock passes into extremely fine, greenish mica slates and phyllites. Besides these dikes others of very large and extremely irregular character also occur. Such is the rock in the bed of Squaw Creek.

The rock from the mouth of Fantail and Nevada Gulches forms a large dike. A specimen from the center and least schistose portion of the dike is a dense deep green rock, and, even in the hand specimen, presents a slightly diabasic appearance. Under the microscope it is seen to be made up of a mass of large plagioclase rods with well developed boundaries. The interstices are filled with a light green uralitic hornblende and some augite.

The plagioclase gives a maximum extinction angle measured in sections perpendicular to albite lamellæ of about 18 to 20 degrees. The feldspar is but little altered. The hornblende is evidently a decomposition product of the augite, for it frequently fills the cavities between the large fragments of that mineral, which shows characteristic twinning and optical properties. The augite, however, is in very small quantities comparatively, and is important only in relation to the origin of the hornblende. The latter is a very light greenish color, and has but a slight pleochroism, from light green to yellowish green, and is most frequently fibrous. It makes up the body of the rock. The next mineral to the hornblende and plagioclase in abundance is a colorless mineral in grains and definite crystals, and scattered in great profusion through the rock. It has a high index of refraction, and was at first taken for pyroxene. The interference colors are, however, extremely low, by which means it may be readily distinguished from that mineral. It is also usually confined to the plagioclase, of which it seems to be an alteration product. The extinction is parallel. In the amphibolite from Squaw Creek this mineral is in very much larger crystals, and in far greater abundance, having developed at the expense of the feldspar. The latter mineral decreases in amount as it becomes a more prominent constituent of the rock. The mineral is probably zoisite.

Accessory ilmenite, calcite, apatite and quartz also occur. The ilmenite is in large masses and is invariably surrounded by a heavy border of leucoxene. The quartz and calcite are secondary.

The other varieties of amphibolite differ from the above largely in degree of alteration and the absence of a recognizable diabase texture. That which forms the large, irregular mass in Squaw Creek is a fine-grained, dense rock, with a light green color, and is locally known as "diorite." The amphibole here, however, is in much greater abundance. It is arranged in wide, fibrous masses, made up of a series of parallel rods, which are often curved and show a wavy extinction.

An analysis of this rock gave

SiO_2	49.19
Al_2O_3,	15.13
Fe_2O_3,	10.71
CaO,	9.55
MgO,	8.05
K_2O,	Not det.
Na_2O,	Not det.

B. GENERAL DISCUSSION OF PETROGRAPHY.

The hills have twice been the seat of prolonged igneous activity. The first period was previous to the metamorphism of the Algonkian series, and was marked by the widespread eruption of basic rocks, now represented by the amphibolites, that occur in such abundance throughout the metamorphosed areas. The second was not until the entire series of sediments between the Algonkian and the upper Cretaceous had been deposited, and was characterized by a highly alkaline series of intruded rocks. These two periods of eruptive activity are separated by such a vast interval of time that it is improbable that there should exist any genetic relationships between the rocks peculiar to them.

Pre-Cambrian Eruptives.

That the rocks of this first period were extremely basic is shown by their petrographic and chemical characters. Further, it seems probable they were intrusive or even plutonic because:

1st: Many of them still preserve the typical diabasic granular texture.

2d: Many of the more massive varieties show the granitoid texture of gabbro.

The rocks are too much altered to afford other than these very general conclusions.

Post-Cretaceous Eruptives.

The rocks belonging under this head may be differentiated into the following:

1. Mica-diorite-porphyry or Hornblende-mica-andesite.
2. Diorite-porphyry or Hornblende-andesite.
3. Tonalite- or Quartz-mica-hornblende-diorite.
4. Quartz-porphyry or Rhyolite.
5. Quartz-porphyrite or Dacite.
6. Phonolite.
7. Quartz-ægirite-porphyry or Grorudite.
8. Augite-vogesite.

Between the first five varieties there are all gradations. The hornblende-mica-andesites contain at times so much orthoclase as to belong more properly in the trachyte series. On the other hand the invariable occurrence of plagioclase in all of the quartz-porphyries and rhyolites, indicates a transition toward the dacites. These relations will be brought out by the accompanying diagram.

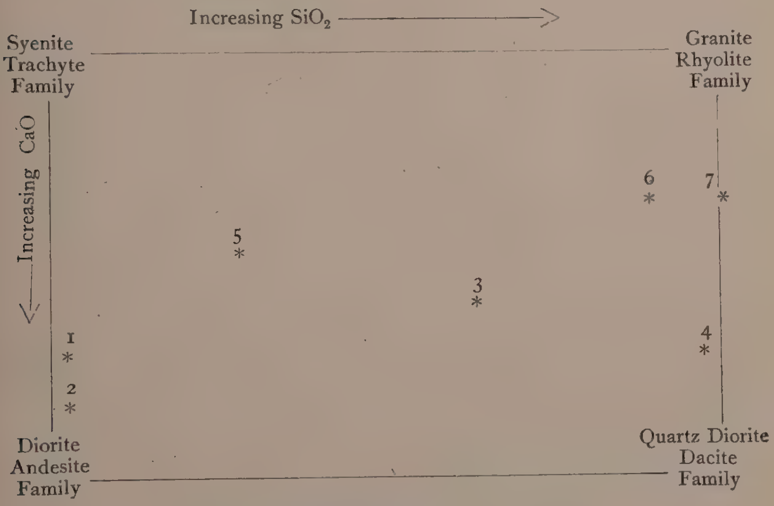


Diagram illustrating affinities of rock types.

1. Diorite porphyry from the Needles to the west of Spearfish Creek. Contains less plagioclase and more orthoclase than typical diorite porphyries, but more nearly approximates them than the trachytes. Described on pages 283 and 284.

2. Typical mica-diorite porphyry from the Rua Mine. Contains much plagioclase, but little orthoclase, and is very basic. Analysis on page 283.

This rock has been described by Prof. Smith as mica-andesite. Described on page 282.

3. Rock from Crow Peak. Contains a very large proportion of orthoclase, but almost all of the phenocrysts are of plagioclase. Enough free silica is present to bring the rock nearer to the rhyolite-dacite line than to that of the trachyte-andesite series, and the plagioclase is in too great abundance

for it to be placed among the rhyolites. Described on pages 284 and 285.

4. This rock is the extremely acidic type from loop on the Fremont, Elkhorn and Missouri Valley Railroad, between Texana and Bald Mountain. Except for its intrusive character it is a typical dacite. Described on pages 285 and 286.

5. Rock described as tonalite, from large dike in Deadwood Gulch. It is intermediate in composition between the granites and diorites, but verges a little toward the syenites from the presence of much orthoclase. Described on pages 286 and 287.

6. Typical quartz-porphyry, in which the quartz is confined to the groundmass, considerable plagioclase is present. Type from Portland Mill exposure. Description and analysis on pages 276 and 277.

7. Foley Peak type of quartz-porphyry. Contains same constituents as number six but shows a great increase in silica. Quartz phenocrysts are abundant. Described on page 278.

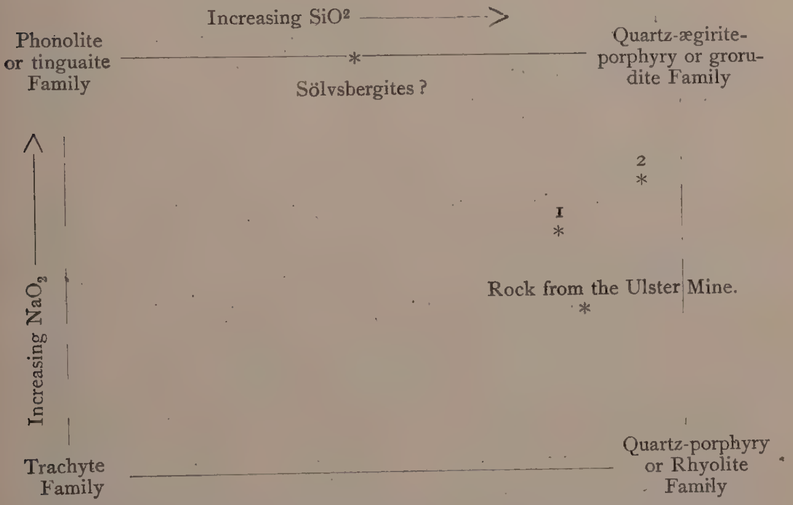
Between the other rocks, namely the quartz-ægirite porphyries, the phonolites and the vogesite, the writer has not been able to trace so intimate a connection. There is, however, a much closer relation between the quartz-ægirite rocks and the phonolites than between either of those varieties and the rhyolite-andesite series.

There is but little doubt that this series of ægirite rocks closely parallels the grorudite-tinguaite series of Broegger. It is true that rocks showing the chemical composition of the solrsburgites have not yet been identified, but very few analyses of the more acid trachytoid phonolites have been made, and there is but little question that further investigation will reveal the presence of the intermediate types.

The difference between these rocks and those described by Broegger are mainly textural. In the grorudites, quartz is confined to the groundmass, whereas in the Black Hills, the equivalent rocks contain it as frequently in the form of phenocrysts. On the basis of this difference the writer has designated the rock as quartz-ægirite-porphyry, thus avoiding the introduction of a new name into the already overburdened science of petrography.

Whether there is any gradation between the quartz-ægirite-porphyries and the quartz-porphyry-andesite series has not been definitely determined. Certain rocks gathered from the complex mass on Foley Peak seem to indicate a transition between these rock types, as also does the larger percentage of soda in the quartz-porphyry from the Ulster Mine.

The following diagram will illustrate the affinities of the ægirine rocks.


Increasing SiO²
Phonolite or tinguaite Family
Sölvsbergites ?
Quartz-ægirite-porphyry or grorudite Family
2
I
Rock from the Ulster Mine.
Increasing NaO₂
Trachyte Family
Quartz-porphyry or Rhyolite Family

1. Rock from Foley Peak. This position as a transitional type is tentative. Chemical analysis is necessary to confirm it.

2. Second specimen from Foley Peak. Position likewise tentative.

Concerning the succession of the different types, a few definite data are available. The mica-andesite or mica-diorite-porphyry on the divide beyond Twin Peaks is cut by a dike of tinguaite. A dike of the same rock intersects the quartz-porphyry of the Portland type, on the western slope of the hill beyond the Rua Mine. Both contacts are clearly visible. The same dike cuts the porphyry of the War Eagle Hill type, in the Gulch below the Rua Mine. The War Eagle Hill quartz-porphyry is again cut in the bed of Squaw creek by a third dike of tinguaite, which strikes east and west. In Bear Gulch the diorite-porphyry is cut by a dike of augite-vogesite, which contains inclusions of the older rocks. One other instance of the kind is mentioned by Professor F. C. Smith.[1] From these data we can infer that:

1. The phonolites are younger than the quartz-porphyries and diorite-porphyries, but their relations to the quartz-ægirite-porphyries and augite-vogesite, is as yet undetermined.
2. The augite-vogesite is younger than the diorite-porphyries.

The vogesite dike is probably one of the latest intrusions, and represents the final basic residuum of the magma which has produced the alkaline series. The point which is still left undetermined is the relation between the latter series and the rhyolite-andesite series. Have we here two series of eruptive rocks marking two widely separated periods of eruptive activity, or a single series which has arisen from the continuous differentiation of a single magma?

It must be left to further investigation to decide this question. The entire area of the northern hills, and the associated Warren's Peak uplift must be studied, and an extended set of analyses made before the relations of the rock types can be established. Such an investigation will be extremely interesting, for there is scarcely any one locality which, from its rare types and from its isolated and circumscribed character, will do more to determine the validity of the hypothesis of magmatic differentiation than the Black Hills of South Dakota.

V. ORE BODIES.

In the district mapped ore bodies occur in all three of the main horizons, Algonkian, Cambro-Silurian and Carboniferous, and in addition there are placers of recent formation. Of these the first was until recently the largest producer, the second is now the most productive, the third is in the early stages of its development, and the fourth is of small importance.

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[1] Transactions of the American Institute of Mining Engineers, Vol. XXVII, p. 413, July, 1897.

The siliceous gold ores occur in the Cambro-Silurian and Carboniferous formations, and are the ones with which this paper is chiefly concerned. The others will be considered only so far as they are geologically related to them.

A. ORES IN THE ALGONKIAN.

The ores in the Algonkian form impregnated zones in the slates and schists. The gold is associated with pyrite, and the ores are free-milling in the upper parts of the deposit, but pass into more refractory sulphurets as workings advance to greater depths. The most important development is the great Homestake vein of Lead City, but many other minor impregnated zones occur throughout the Algonkian exposures. The ores in this formation average $3.87 to $4.00 per ton, and are essentially low grade. Concerning the Homestake vein Dr. Carpenter says:[1] "The part of the 'belt' belonging to the Homestake combination is gold bearing for a distance of 6,000 feet. The 'ore' is not continuous throughout this distance, but occurs in shoots or vast 'pipes,' lenticular in cross-section. The beds of argillite, phyllite and amphibole schists, in which these shoots occur, strike north 37¾ degrees west; which is also accurately the strike of the plane or 'ore channel' in which the shoots occur. The dip of the beds is as a whole to the east. The shoots dip east also, but athwart this plane at an angle of about 45 degrees. The ore and enclosing rocks have indifferently the same general cleavage structure."

Many dikes of porphyry cut the Homestake deposits, and sheets of the same rock overlie it. The porphyries have, in the opinion of the above authority:[2]

1st. Made the ores more free-milling.

2d. Produced in their neighborhood either an enrichment of the deposit or a further concentration of the gold which originally existed in it.

As these deposits have not yet attained, in the area mapped, any considerable importance, they will not be further discussed. The important points are:

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[1] Trans. Am. Institute Mining Eng., XVII, 574, Feb., 1889.

[2] Op. cit., page 575.

1st. They are the oldest known gold deposits of the hills.

2d. Their mineralogical character is largely free-milling in the upper portions—and hence free-milling in those parts which, by their disintegration, have furnished material for the formation of later deposits.

B. ORE BODIES IN THE CAMBRO-SILURIAN.

From the disintegration of the Algonkian ore deposits we have, as demonstrated by Devereux,[1] ancient placers, in which the gold exists in the free condition. These are in the basal conglomerates of the Cambrian, and the gold has been worn from the older deposits by the action of the waves upon the shores of the Algonkian Island. They have been of especially large development in the vicinity of Central City in Deadwood Gulch, and in Blacktail Gulch. But the free gold of the Cambrian formation is not confined to the basal conglomerate, which indeed is by no means auriferous throughout its entire extent. The gold seems to be disseminated throughout the formation, sometimes sinking to a very few cents per ton, but almost always giving colors when panned. Cambrian shales and sandstones, some two or three hundred feet above the basal quartzite on the west banks of Spearfish Creek have yielded from 80 cents to $2.00 per ton, and are here entirely unaltered. They contain the original high percentage of calcareous matrix between the quartz grains, and show no traces of induration. Certain unaltered glauconite shales on Crown Hill have yielded, according to Mr. Holmes of the Rua Mine, considerable colors on panning. Many other instances of free gold in small quantities in the unaltered Cambrian shales have been mentioned to the writer. Time has not permitted an extended series of tests, but if the numerous instances cited are correct, and there seems to be no reason to doubt them, small quantities of free gold would seem to be a common feature in many of the Cambrian sediments, and to have been deposited from the erosion of the Algonkian throughout a large portion of Cambrian time. This gold has not, however, at any time been of economic importance (except in the basal conglomerates), and is interesting only as related to the formation of other deposits.

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[1] Trans. Am. Institute Mining Eng., X, 465 and sqq., Feb., 1882.

The Cambrian Siliceous Ores.

The siliceous ores are perhaps the most interesting ore bodies in the hills, and now outrank the Homestake properties in their output. Their occurrence, history and treatment have been set forth by F. C. Smith in an excellent paper on the subject. Other papers are those of F. R. Carpenter, W. P. Jenney, Persifer Fraser and W. O. Crosby.

Distribution.—The producing districts have been divided by F. C. Smith into the northern connected area, which is essentially that included in the map accompanying this paper, and the Galena area. In the first are the ores carrying gold and silver, and in the second those with gold, silver and lead. The first area only will be considered here.

The northern connected areas of Smith is roughly divisible into four parts :

1. Ruby Basin or Bald Mountain district.
2. Portland or Green Mountain district.
3. The Crown Hill district.
4. Sheeptail Gulch district.

1. *Ruby Basin District.*

The Cambrian strata are most extensively exposed in the vicinity of Ruby Basin and Bald Mountain, and therefore the ore-bearing horizons have been most easy of access in this vicinity. Consequently this district has so far attained the greatest development. The number of mines which have been either operated, or are now in operation, is very large, and it has been possible to examine only a limited number of them in detail.

The following properties may be cited as illustrative of those which are, or have been, large producers : The Tornado, the

Union, the Big Bonanza, the Little Bonanza, the Baltimore, the Ross-Hannibal, and the Fanny. There are also many others. Of these the writer has examined the Union and the Big Bonanza, and in addition many abandoned workings.

The Union Mine.—The Union Mine is situated in Whitetail Gulch, just west of Sugar Loaf Hill. The shaft has been sunk through the base of the Sugar Loaf laccolite into the shales and sandstones of the Cambrian, as far as the top of the conglomeratic quartzite, which immediately overlies the Algonkian. See Fig. 15. Upon this quartzite the ore occurs as "Shoots" or long flat channel like masses, which have in general a north and south direction. In thickness the shoots vary from a thin

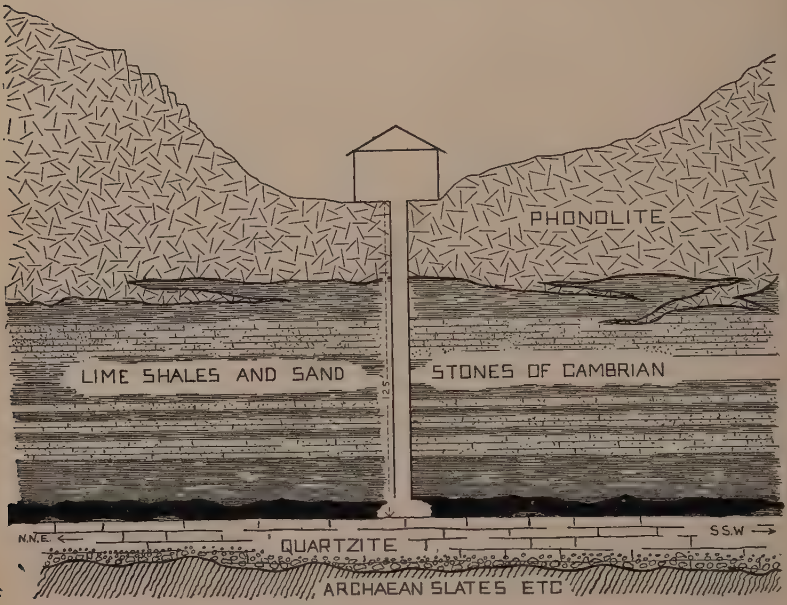

FIG. 15. Diagrammatic section of the Union Mine in Whitetail Gulch. The section is supposed to be in a north and south direction. The shaft was sunk some distance east of the ore shoot but the ore has been shown in the diagram at the foot of the shaft to illustrate its occurrence immediately above the basal Cambrian quartzite.

edge to seven or eight feet. Above is a roof of lime shales. The width of the shoots is roughly from 20 to 150 feet, and in length they are much greater. The central portion of a shoot is usually the thickest, and on the flanks the ore thins out laterally, with irregular boundaries. It sometimes passes into shales in alternating layers of different degrees of silicification, and again it thins down to a feather edge. When a shoot has been mined out, narrow vertical fissures filled with ore can be detected, which are roughly parallel to the longer diameter of the ore body, and may be seen both in the shale roof above and the quartzite floor beneath. In the latter they are much constricted and frequently thin down to a mere streak. They often fork, and are sometimes cut by cross verticals, but in general they follow roughly the longer direction of the shoot. Throughout the entire mine ramifying dikes and sheets of phonolite occur in great profusion, and in some instances the ore verticals can be seen alongside of them, the solutions evidently having had access through contact zones. The character of the ore is essentially oxidized, and is a very hard siliceous material, which is heavily coated and intermingled with iron oxides. The ore is in all cases a replacement of the calcareous material of the shales and sandstones by siliceous solutions, which contained the valuable mineral.

In many places a gray to blue, dense rock is met, which has almost the appearance of a diorite, and which forms the borders of the ore-shoots. It is called "sand-rock" by the miners and was found on examination to be a quite pure crystalline limestone, but to contain disseminated sand grains and considerable pyrite.

The bluish variety, when exposed to oxidizing conditions becomes red, and in the most highly altered occurrences is a light, reddish, sandy material from which the greater part of the lime has been dissolved. It is then termed "red gouge" by the miners. This rock, in either the blue or unoxidized, or the red and oxidized state, is present in all mines of siliceous ore, and seems, from its highly calcareous nature, to have everywhere formed the ore-bearing horizon. That the siliceous ore-shoots occur prevailingly on the basal Cambrian quartzite is probably due to the position of this easily replaceable limestone rather than to any influence exerted by the quartzite itself.

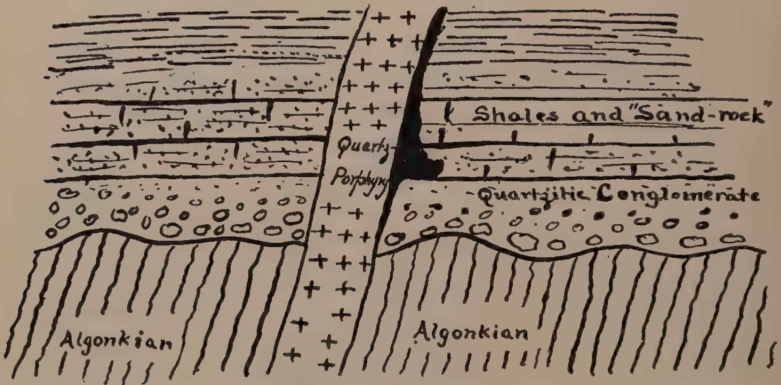

FIG. 16. Siliceous ore vertical occurring along the contact of a quartz-porphyry dike near the opening of the Big Bonanza Mine.

The Big Bonanza.—The Big Bonanza Mine is situated on the southern bank of Fantail Gulch, just at the lower end of the town of Terry. The basal quartzite is here exposed high up on the side of the gulch and the ore has been opened up by a drift. The shoot is of an irregular character, and occupies nearly the entire area covered by the claim. It attains in places a thickness of fifteen feet, and is of both the blue or unoxidized, and the red or oxidized varieties. The floor is of the usual quartzite, but the roof is sometimes porphyry, and at others shales. Verticals occur as usual, with a prevailing north and south trend. An interesting vertical on the contact of a quartz-porphyry dike was seen (see Fig. 16) near the mouth of the main drift.

Of especially frequent occurrence in this mine is the "barren sand rock," by which is meant the hard blue crystalline limestone mentioned above. At one point the ore shoot is completely cut off by this rock, but it is seen again at some distance. The limestone forms a thick mass like a dike in close contact with the ore on both sides. A large phonolite dike some hundred feet or more in width occurs at the west of this mine and separates the ore body from that of the Little Bonanza.

Other Mines.—Of the remaining mines in the Ruby Basin, the most important is that of the Golden Reward Company. It is the largest producer of this class of ore in the hills. The writer was unable to obtain access to the Golden Reward properties, but presumably the ore shoots show no difference from those just described except perhaps in size. Mention has been made by Prof. Smith[1] of several horizons at which the ore occurs in this region, but he has stated that these may be due to faults. This has undoubtedly been the case, for the Algonkian itself has been faulted to a very considerable extent in Nevada Gulch, and many other faults can be readily distinguished.

2. *Portland or Green Mountain District.*

In this district all of the mines with one exception, the Decorah, are situated from two to three hundred feet above the base of the Cambrian. On Green Mountain and almost immediately beneath the phonolite cap are the Trojan and Empire State, the upper workings of the Decorah and other mines. Along the Burlington and Missouri River Railroad are the Clinton, Mark Twain, and Gunnison mines. In the bottom of Deadwood Gulch, and separated by a thickness of two or three hundred feet of strata from the upper working of the same mine on Green Mountain, is the Decorah.

The Decorah.—In the Decorah mine the conditions are the same as those in the Union and Big Bonanza, the ore lying directly on the quartzite. The mine is however, in the early stages of its development, and no very extensive ore shoots have yet been mined out. One peculiar feature of the mine, and one which is met at no other place to the writer's knowledge, is that the basal quartzite is thinner than usual, and seems to occupy only the depressions of the Algonkian surface, so that the ore frequently comes into direct contact with the slates. The roof is sometimes shales, and at others porphyry, and the entire mine, like many of the others examined, is seamed with dikes.

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[1] Trans. Amer. Inst. Mining Engineers, Vol. XXVII, p. 416. July, 1897.

The Clinton.—Of the mines on the upper contact the Clinton was the only one carefully examined. The shoots extend in a northwest and southeast direction, and the usual verticals appear. The ore is in a bed of lime shales, and rests on a quartzite floor consisting of one of the more massive members of the upper strata of the Cambrian. The shoots are thin and of less lateral extent than are those on the lower quartzite, but in other respects they show no essential difference. The hill on which the mine is situated contains many sills of porphyry with Cambrian partings between. Much of the ore is of lower grade than the ores on the lower contact, and it is said to carry a higher relative percentage of silver.

Although the very first siliceous deposits to be opened up in the hills, the mines of Green Mountain have not been in operation for some time, owing to litigation. The ores, however, carry quite high values in gold and silver. They contain considerable galena and some copper, which frequently manifests itself in green coatings.

3. *Crown Hill District.*

In the Crown Hill district very little work has yet been done, there being but one producing mine, that of the "Two Johns." The district is, however, a promising one, and owes its tardy development rather to ill-advised mining, and to its position at the very top of the Cambrian series (thus necessitating a considerable depth of shaft to reach the lower quartzite) than to any absence of ore deposition. In the Two Johns the ore lies on the lower quartzite.

4. *Sheeptail Gulch District.*

The ore is found in shoots on the basal Cambrian quartzite, as it dips away from the Algonkian toward the northeast. This

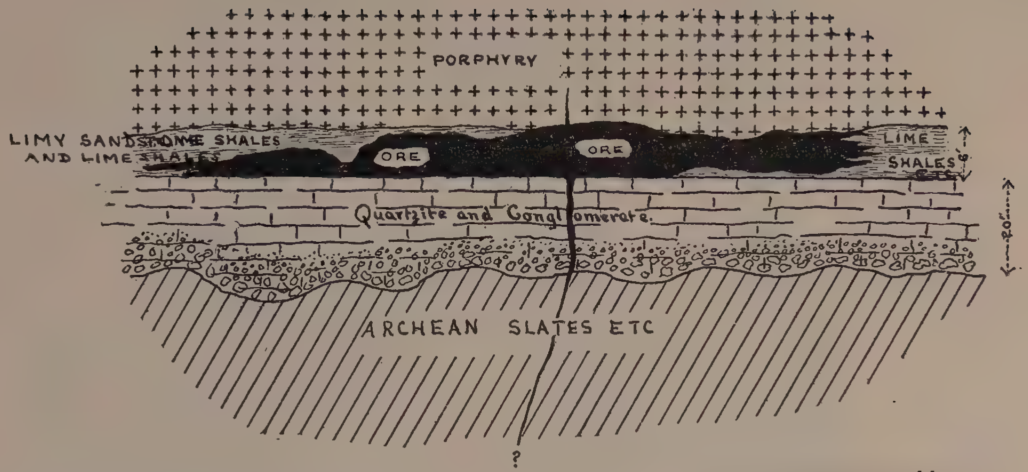

FIG. 17. Diagrammatic section of ore shoot in American Express mine illustrating occurrence of barren, unreplaced portions of the calcareous sandstone.

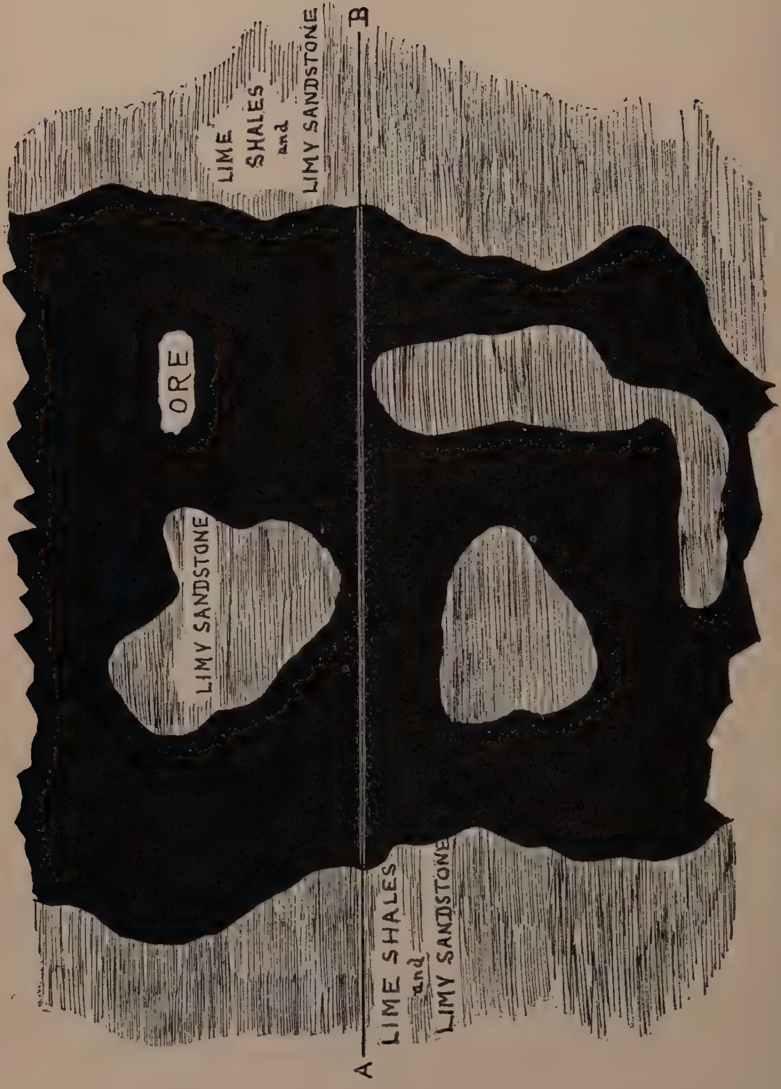
LIME SHALES and LIMY SANDSTONE
B
ORE
LIMY SANDSTONE
LIME SHALES and LIMY SANDSTONE
A

Fig. 18. Diagrammatic plan of ore shoot in American Express mine illustrating occurrence of barren, unreplaced portions of the calcareous sandstone.

occurrence of Cambrian is not represented on the map as the limited time at the writer's disposal did not permit an accurate study of the exposures. The district is still in the early stages of development.

The American Express Mine is situated in Sheeptail Gulch, a short distance above its junction with Blacktail Gulch. It is opened by a tunnel on the basal quartzite, which is here exposed at some distance above the bottom of the gulch. The quartzite dips slightly toward the northeast, and the ore shoots run with the dip, being lateral enrichments of verticals. The ores have come up from below, and spread out upon the quartzite floor, replacing the calcareous matter in the sandy limestone and lime shales. The shoots vary from a few feet to thirty feet in width, and in thickness they are about six feet. The roof of the mine is a porphyry sheet. The average yield of the ore is something between $15.00 and $25.00 per ton. It is of the hard, bluish, unoxidized variety, and contains many vuggs filled with quartz. Druses of pyrite can often be seen in the hand-specimens. The verticals run northeast and are parallel with the longer diameters of the shoots. Islands of unreplaced "sand rock" (the "barren sand rock" previously mentioned) or sandy limestone occur in the shoots. The accompanying diagrams will illustrate the geological relations. (Figs. 17, 18.)

Résumé Regarding the Siliceous Ore Bodies. Form.—From these data it will appear that the ore shoots are channel-like masses of irregular shape, but generally longer than broad. They sometimes attain a thickness of fifteen feet and again may sink to a feather edge. The roof is either a porphyry sheet or a bed of shale, and the floor is either the hard indurated basal quartzite of the Cambrian or in the case of the upper contact a bed of argillaceous and non-replaceable shales. Vertical feeders run in a direction parallel to the longer diameters of the shoots. The width of the ore bodies varies from 150 feet to a mere vertical crack. The thickness seems to have been determined partly by the thickness of the more easily replaceable rock, *i. e.*, that containing the most fissures, and the largest proportion of calcite, and partly by the strength and volume of the siliceous solutions. The width of the shoots is dependent on the latter condition, the length, upon the length of the supplying fissures. Fig. 19 illustrates the general type of siliceous ore-body in the Cambrian.

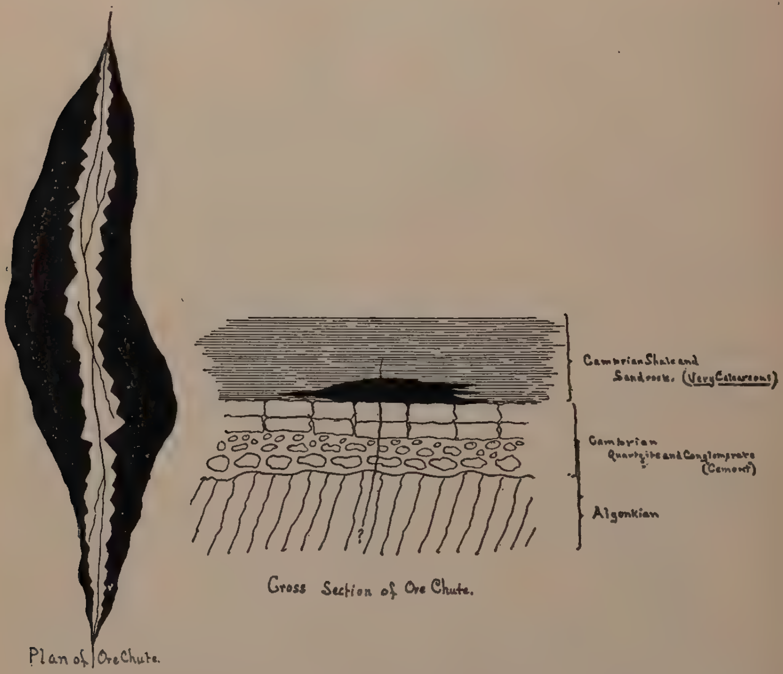
Cambrian Shale and Sandrock. (Very Calcareous)
Cambrian Quartzite and Conglomerate (Cement)
Algonkian
?
Cross Section of Ore Chute.
Plan of Ore Chute.

FIG. 19. Generalized plan and section of a siliceous ore shoot in the Cambrian shale. The plan of the shoot is broken at the center, to illustrate the general parallelism of the vertical to the longer diameter of the ore-body.

Horizons.—The horizons of the ore bodies are first, that of the sandy limestone immediately overlying the basal Cambrian quartzite and, second, other horizons near the top of the same series, but not definitely determined. The larger number of mines have been opened upon the lower horizon, and as compared with the upper, it has so far proved to be superior both in the frequency and size of the shoots, and in the grade of the ores. That this is a general rule can only be demonstrated when those districts from which the upper measures of the Cambrian have not been eroded have been more completely opened up.

It seems, however, reasonable, that such should be the case when we consider that the lower horizon is the first replaceable zone to be attacked by uprising solutions, and that unless porphyry intrusions have rendered it difficult of access, the solutions would in general first expend their strength in its replacement; the mineralization of the upper contacts would then only be performed by solutions of unusual strength and volume.

Character of the Ores.—Of the character of the ores Professor Smith says :[1]

> "While some deposits (such as that of the Dividend Mine, on Green Mountain) yield pay-ore of a gouge-like, decomposed character, in general the ores may be described as thoroughly reorganized sandstones, showing, under the microscope, many druses lined with innumerable quartz crystals, and containing calcite and fluorite. Of these ores, those which have not suffered oxidation frequently show considerable fine grained pyrite, and are locally called 'blue' ores; the oxidized ores, though frequently showing only a small iron content, are usually stained with iron, and are called 'red' ores. Both kinds are usually exceedingly tough and difficult to break or pulverize.
>
> "Analysis of typical samples yielded the following results :

RED ORE.

Silica..	84.45%
Alumina.	4.07
Ferric Oxide.	7.28
Calcium Oxide	0.85
Magnesium Oxide	0.25
Sulphur trioxide	3.71
Tellurium	8.426 oz. per ton.
Gold	0.574 " " "
Silver	2.875 " " "
Total	100.61

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[1] Trans. American Inst. Mining Eng., XXVII, 415.

[2] See "Tellurium and Gold Ores," *Trans. Am. Inst. Mining Eng.*, XXVI, 485, Sept., 1896.

BLUE ORE.

Silica	68.748%
Alumina	3.072
Iron	13.289
Sulphur	11.728
Gypsum	0.833
Fluorite	0.784
Phosphorus pentoxide	0.842
Tellurium 4.03 oz. per ton	
Gold 0.325 oz. per ton	
Silver 10.55 oz. per ton	
Total	99.296

"These may be considered as low-grade ores, and it is interesting to note that the analysis of the red ore might be almost duplicated by that of the blue ore, after oxidation, during which the latter might be expected to lose iron and sulphur.

"Taking averages of the tellurium, gold and silver found in the analysis of nine different samples of Potsdam ore, six being 'red' and three being 'blue,' the following percentages were obtained :

"Tellurium	59.97%
Gold	7.64
Silver	32.39
Total	100.00"

Much discussion has taken place over the form in which the gold exists in these ores. Little or no free gold ever occurs in them, and the only mineral which would contain the gold is the pyrite, which can always be detected in considerable quantities in the unoxidized varieties. Since the publication of the paper above quoted, Professor Smith informs me that spectroscopic investigation has revealed the presence of considerable thallium in the ores.

The value of the ores varies within wide limits, running anywhere between $6.00 and $60.00 per ton, and, in some instances, even higher. The average yield is, however, from $15.00 to $20.00 per ton. Owing to the expense of treatment, ores below $10.00 per ton have not yet been mined at a profit.

Origin of the Ores.—The nature of the ore bodies and the character of the ores will at once make it manifest, that they are to be regarded as chemical replacements of the calcareous material of sandy limestones and lime shales by siliceous solutions bearing the gold. The deposition has in all cases been a metasomatic interchange of silica and pyrite for carbonate of lime, in which the latter has in all probability acted as the precipitating agent. Whether or not these solutions were in a heated condition, it is not possible to say, but it is very probable that such was the case. That the chemical activity of the solutions was due to the eruptive activity seems probable because at a distance from the eruptive centers, ore bodies are not found. The gold remote from the eruptives is either in placers or in finely disseminated colors in the Cambrian, and has been derived in all probability by erosion from the Algonkian schists. The ore shoots can invariably be traced to a so-called "vertical" or crevice, now filled by silica of the same character as the ore body itself.

At times these verticals occur at the sides of dikes of quartz porphyry, but more frequently they are merely fractures in the sedimentary rocks, probably caused by the same eruptions that heated and rendered active the percolating waters to which the ore bodies owe their origin. Prof. Smith has said[1] "Wherever mineralization of the Potsdam beds has occurred, it can almost always be traced to a quartz-porphyry or rhyolite dike, or 'vertical' which itself is usually mineralized, stained with oxide of iron, and so much broken and decomposed, that its rock character is distinguishable with difficulty."

That all the verticals which occur in relation with these ore bodies are shattered and subsequently mineralized dikes the writer does not believe, because in many cases they show no traces of the original rock, and the siliceous replacement of porphyry is something which is not frequently observed. That the verticals do sometimes occur along the contacts of the dikes is not to be denied, but this is to be attributed to their shattered condition caused probably by the injection of later intrusions. The verticls are to be considered simply as fractures, which have afforded access to percolating waters. They have sometimes occurred along the contacts of dikes, but are as frequently removed from them.

[1] Trans. American Inst. Mining Eng., Vol. XXVII, pp. 416, 417. July, 1897

It has been shown on page 293 that there are at least two series of intrusions—first the rhyolite-andesite series, and second the series involving the phonolites. The phonolites are the later intruded rocks. The question now arises, is it to one or both of the series of intrusions that the mineralizing action is attributable? To this a positive answer cannot be given, but the widespread occurrence of purplish fluorite, and the presence of tellurium in the ores are so similar to the conditions at Cripple Creek, and in the Judith Mountains, that one cannot well avoid considering the phonolite here, as there, to be the chief agent that has rendered ore bearing solutions chemically active.

Derivation of the Gold.—For the derivation of the gold four possible sources can be suggested :

A. By lateral secretion.	1. From the leaching out of the small amount of free gold present in the rocks of the Cambrian formation.
	2. From the leaching out of small amounts in the porphyries.
B. By accension by infiltration.	3. From the leaching out of the free gold and sulphurets of the underlying slates and schists.
	4. From the derivation of the gold from an indefinite horizon below, *i. e.*, probably the same source from which the Algonkian gold was derived.

The form of the ore shoots and their association with verticals, will make it at once apparent that the ores are not in any sense the result of lateral secretion, but that they have come from depths far below their present position.

We are then left to decide whether the solutions have derived their burden of gold, from the older deposits in the Algonkian, or from deeper sources below. It is not improbable that both of these explanations are true. Tellurium it is true, has not yet been detected in the Algonkian ores, but it may exist in the sulphurets in depth.

The history of the formation of the siliceous ore bodies can then be outlined as follows :

First occurred the intrusion of the older quartz-porphyries, which produced much shattering. Contemporaneous with these, there may have been a certain amount of ore deposition, but not that to which the main siliceous ore bodies owe their origin. Later the eruption of the phonolites took place, cutting and shattering the older eruptives, and adding to the number of fissures in the sedimentary rocks. Subsequent to all of these intrusions, and probably separated from them by only a brief interval of time, came a long period during which heated solutions, containing fluorine and silica and other powerful mineralizers gradually replaced the carbonate of lime in the more soluble strata of the Cambrian. The chemical activity of these solutions was increased by the heat and mineralizers derived from the newly injected phonolites. They passed up through the Algonkian slates and schists, becoming much enriched by the leaching out of the gold from these rocks. Finally they reached the very calcareous and porous rocks of the Cambrian, and by a metasomatic interchange, produced the horizontal ore bodies that are found to-day.

C. Ores in the Carboniferous Limestone.

Of these ores there are two classes : Silver ores and gold ores. The silver ores occur in the vicinity of Carbonate Camp on the north side of Squaw Creek, and are mainly chlorides and carbonates. They have not been studied with care. Of the gold ores in the Carboniferous there is but one district.

The Ragged Top District.—This includes two varieties of deposits, one of which is represented by the Ulster Mine on the divide to the northwest of Preston, the other by the verticals on the Dacy Flat, and on the divide to the south of Ragged Top Mountain. The Ragged Top verticals are seven in number, the Dacy vertical being the largest producer. They are wedge-shaped crevices in the limestone, of about ten feet in maximum width at the top and narrowing down to mere crevices in depth. In the Doyle vertical lateral enrichments occur and also in the Metallic Streak Mine on the ridge south of Calamity Creek.

The ore is essentially a silicified mass of brecciated limestone fragments, which are stained with iron oxide and which contain calcite in the lower grade ores. The general run of ore, however, is hardly to be distinguished from the limestone except that it is very slightly darker and is very hard, being an almost complete replacement of the limestone. Porphyry is not present in these verticals.

The line where the ore is cemented to the wall rock (see diagram) is often clearly marked, but the structural details, such as banding etc., pass from the one into the other, and it is only possible to tell them apart, from the slightly darker color and greater hardness of the ore. The ore in the Metallic Streak Mine, is often brilliantly stained with fluorite. No

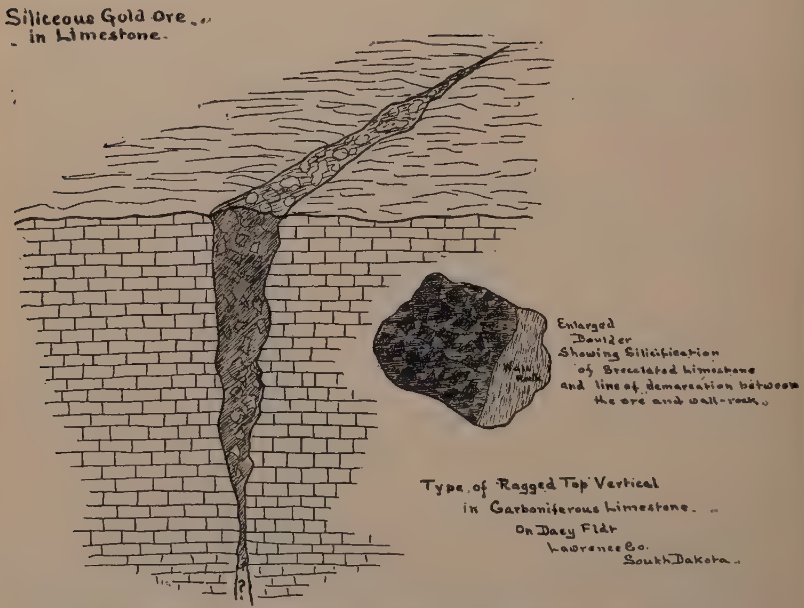

Siliceous Gold Ore
in Limestone.
Enlarged Boulder Showing Silicification of Brecciated Limestone and line of demarcation between the ore and wall-rock.
Wall Rock
Type of Ragged Top Vertical in Carboniferous Limestone.
On Dacy Flat
Lawrence Co.
South Dakota.
?

FIG. 20. Diagram in perspective to illustrate the character of the Ragged Top Verticals.

authoritative data as to the grade of these ores, but they are reported to yield high values, frequently over $100 per ton. In the case cited below the value in gold is unusual. They are to be regarded as brecciated zones silicified by solutions, which owe their activity possibly to the influence of the eruptive mass of Ragged Top Mountain.

The chemical character of the ore will appear from the accompanying analysis taken from the paper by Professor Smith :

Moisture		0.110
Volatile matter		0.802
Silica		90.990
Alumina		2.970
Ferric Oxide		3.024
Calcium Oxide		1.138
Magnesium Oxide		trace
Tellurium	29.26 oz. per ton.	
Gold	17.34 " " "	
Silver	1.21 " " "	
Total		99.034

Combining the gold, silver and tellurium in the above analysis we find them existing in the following relative proportions,

Tellurium	61.20
Gold	36.27
Silver	2.53
Total	100.00

The Ulster Mine.—In the Ulster Mine the ore occurs in contact zones, between the limestone and a very irregularly intruded mass of porphyry. This is cut by a dike of dense green phonolite, and the ore seems to have resulted from the silicifications of brecciated limestone, which has been fractured by the intrusion of Twin Peaks and other porphyry bodies in the Cambrian below. Brilliant purple fluorite occurs in great quantities. The ore is irregularly distributed. It may thin to a mere streak, and again open out to a very large and thick mass. The values obtained are very high, running frequently up to $150 per ton, and in one instance $1,000 per ton.

From these descriptions it will appear that there is no marked difference between the siliceous ores in the Carboniferous and those in the Cambrian. Like them, they are to be ascribed to the chemical action of siliceous solutions replacing calcite. That they are vertical in the majority of cases, horizontal in the case of the metallic streak, irregular as in the Ulster, is merely a question of the direction and form of the fissures through which the solutions obtained access to the limestone. Their existence in the Ragged Top region would seem to indicate the probable presence of extensive ore deposits in the Cambrian below. Indeed it is probable that as the development of the latter class of ores goes on the distribution of the shoots will prove to be much more general than is at present apparent.

D. Placers.

The quarternary placers have been formed by the concentration of the gold derived from the Algonkian. They are distributed in considerable numbers in the neighborhood of the great Homestake belt, and in fact in many of the gulches, which head up into the Algonkian areas throughout the hills. Professor Smith mentions them and says: "The yield from these workings is relatively small, and there seem to be a few places where the placers could be profitably worked on a larger scale; nevertheless, they afford occupation to a large number of men, and yield them a constant if small return."

The placers in Beaver Creek, Bear Gulch and Iron Creek are of this type, and, although occurring in the Carboniferous formation, have undoubtedly derived their gold from the Algonkian of Nigger Hill. When panned the gold is found mingled with great quantities of tourmaline and cassiterite, and innumerable small red garnets, which could have come from no other source.

The richest placers are, however, not directly formed from the disintegrated Algonkian, but have been shown by Devereux to have resulted from the erosion of the "cement" deposits or auriferous basal conglomerates of the Cambrian.

E. Acknowledgements.

In conclusion the writer takes pleasure in extending his acknowledgements for the many courtesies extended to him while in the hills: to Professor F. C. Smith for very kind advice as to field work, localities, etc., and for the published analyses, which have been invaluable in the preparation of this paper, also for many other kindnesses; to Dr. F. R. Carpenter and Messrs. Chapman, Greenough, A. J. Smith, Johnson, Jackson and Hallam for permission to examine mining properties; and to Dr. W. P. Jenney for courtesies extended. After the completion of field work the writer accompanied Dr. T. A. Jaggar, of the U. S. Geological Survey, in his reconnaissance of Custer Peak, Inyan Kara, Black Butte, Sundance hills, Little Missouri Buttes, Mato Tepee and Warren Peaks. Great care has been taken to make no reference in this paper to these igneous peaks, other than to facts already published, but their study has been an invaluable aid to a correct understanding of the igneous phenomena in the district studied, as also have views suggested by discussion with Dr. Jagger. For many other courtesies the writer is also indebted to Dr. Jagger and Messrs. Tower, Herron and Boutwell of the U. S. Geological Survey.

In the preparation of the petrography much aid was rendered by the sections of Norwegian types kindly loaned by Dr. Henry S. Washington.

To Mr. Van Ingen, of Columbia University, and to Messrs. P. [illegible] Irving and J. F. McClelland, the writer is indebted for assistance in the preparation of the model of Ragged Top and Elk Mountain and for many other services.

To Professor Kemp, of Columbia University, the writer especially extends his acknowledgements for advice and assistance during the field work and for kindly criticism and revision throughout the entire preparation of this paper and also for laboratory and other facilities for investigation kindly placed at his disposal by the geological department.

PLATE V.

PLATE V.

BLACK HILLS GEOLOGY.

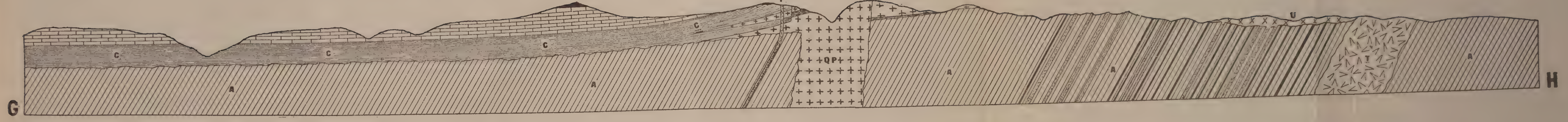
Map illustrating a portion of Lawrence county in the Black Hills of South Dakota.

PLATE VI.

PLATE VI.

BLACK HILLS GEOLOGY.

Geological cross-sections taken at lines shown on the map, Plate V. and drawn to same scale.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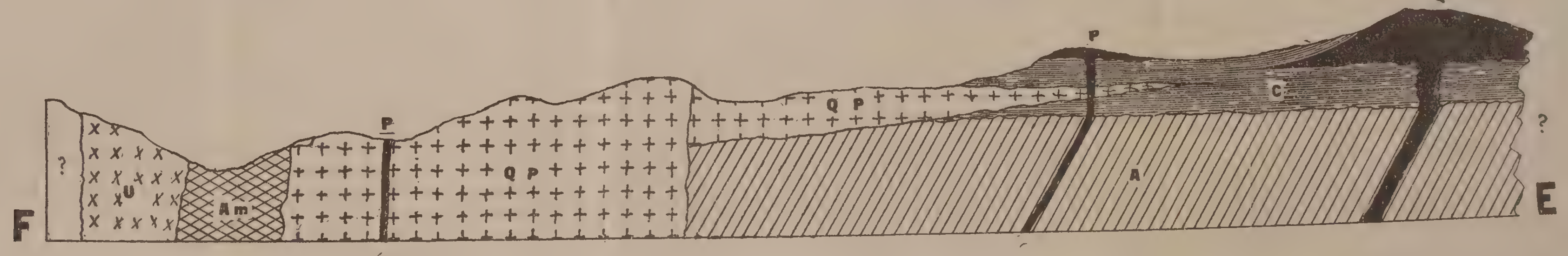
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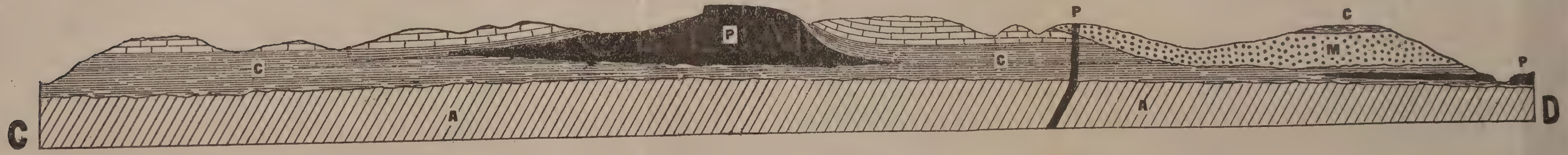
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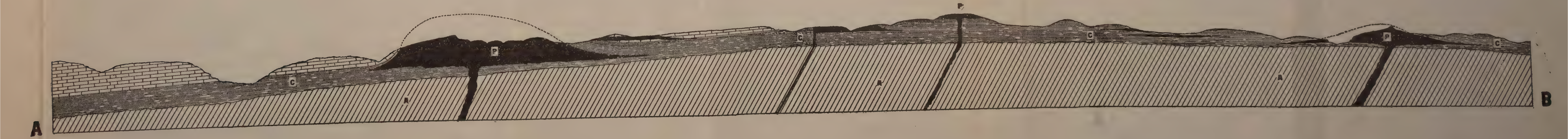
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PLATE VII.

PLATE VII.

BLACK HILLS GEOLOGY.

Specimen of micaceous slate taken from the De Smet Cut, showing slaty cleavage cutting the original sedimentation planes. Actual size of specimen about six by five inches.

See page 197.

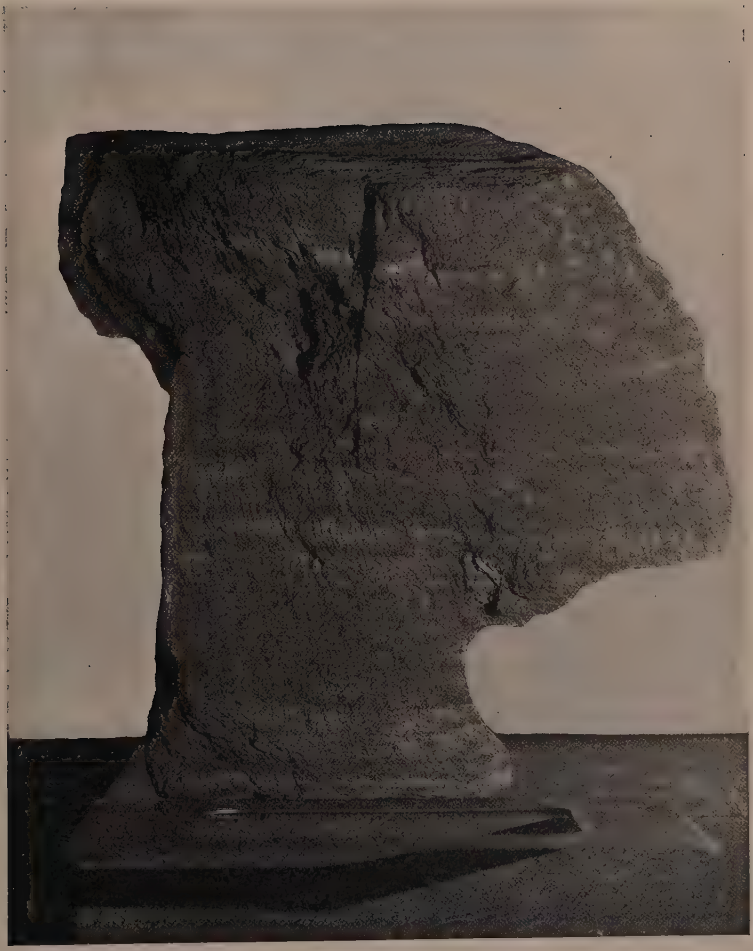


PLATE VIII.

PLATE VIII.

BLACK HILLS GEOLOGY.

Upper sandstones and shales of the Cambrian formation as seen from Fremont, Elkhorn and Missouri R. R.
See page 200.

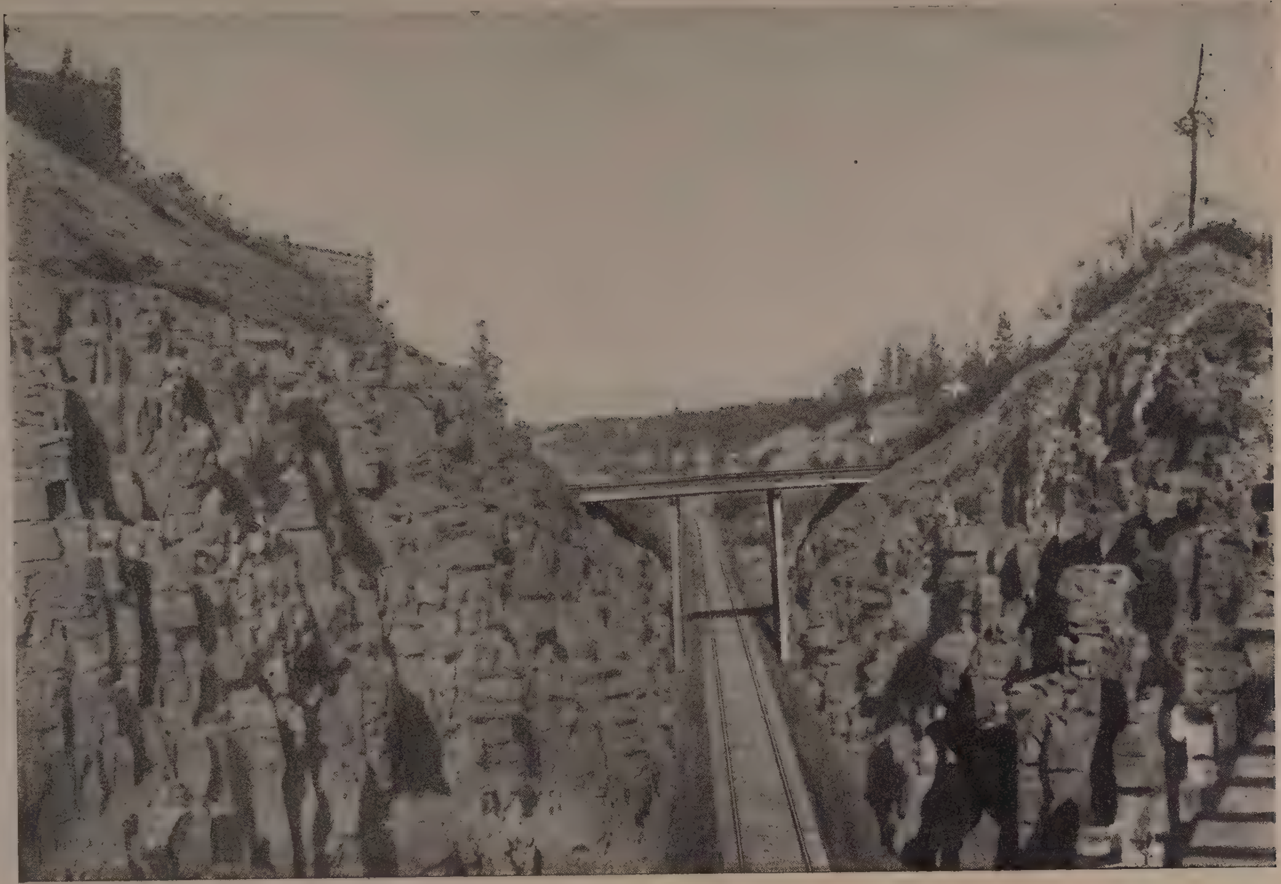


PLATE IX.

PLATE IX.

BLACK HILLS GEOLOGY.

Platy cleavage in phonolite. Sugar Loaf Hill laccolite.
See page 211.

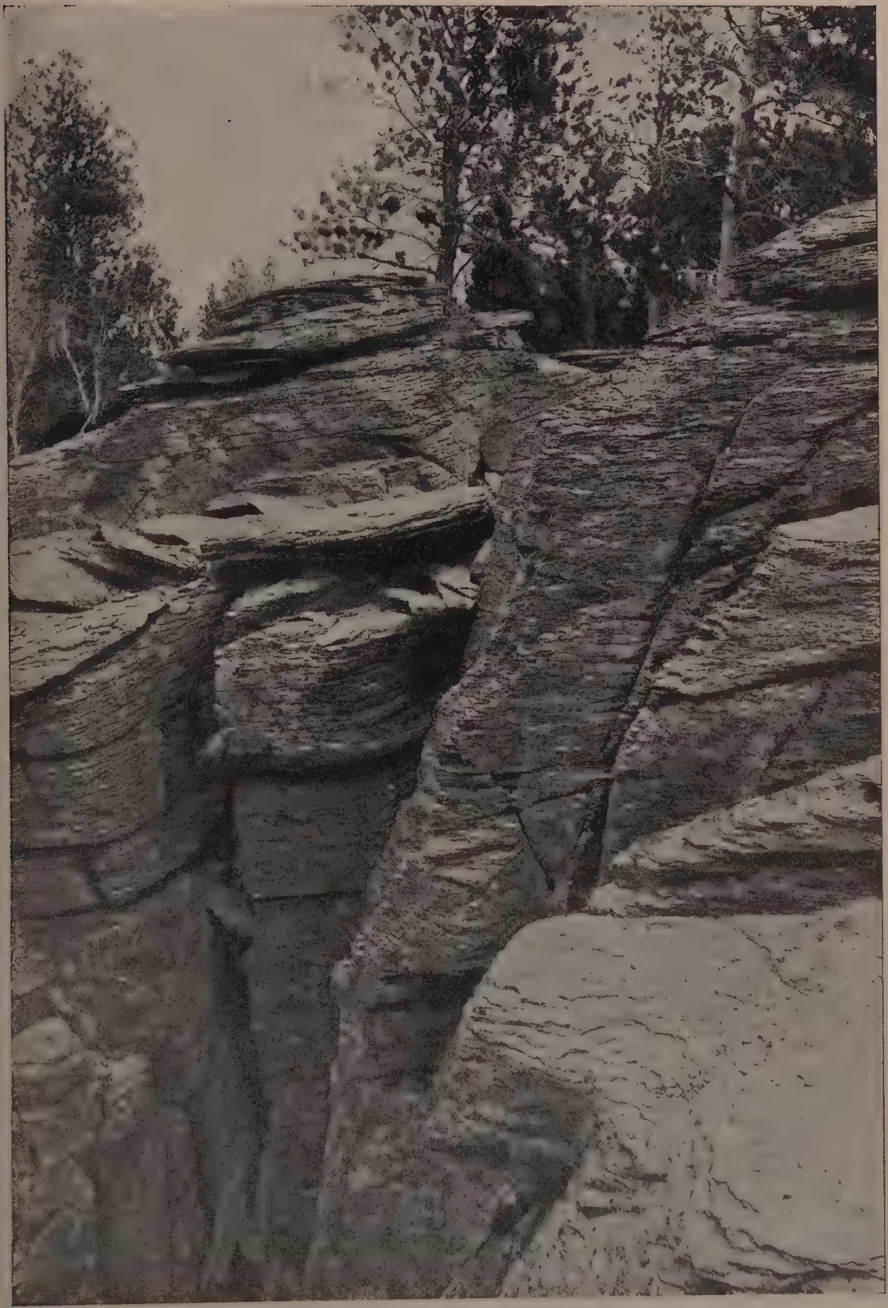


PLATE X.

PLATE X.

BLACK HILLS GEOLOGY.

Ragged Top and Elk Mountains as seen from Crown Hill. Ragged Top is the low lying hill to the right, Elk Mountain is the higher and more sharply pointed hill to the left.

See page 212.

PLATE X.

PLATE XI.

PLATE XI.

BLACK HILLS GEOLOGY.

Fig. 1.—Near view of the western end of Ragged Top Mountain.
See page 213.

Fig. 2.—Ragged Top Mountain as seen from the top of Elk Mountain.
See page 213.

PLATE XII.

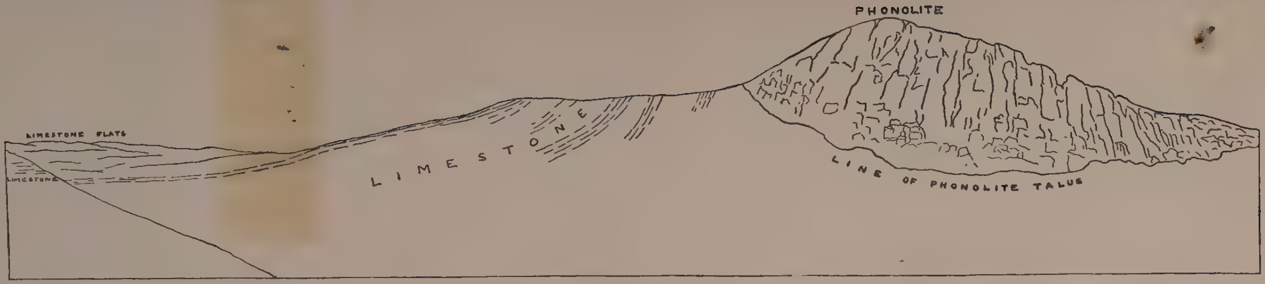
PLATE XII.

BLACK HILLS GEOLOGY.

Fig. 1.—View of the southwestern side of Ragged Top Mountain, showing the upturned strata on the west.
See page 214.

Fig. 2.—Tracing made from figure 1 to show the relation of the upturned limestone to the phonolite of Ragged Top Mountain.
See page 214.

PLATE XII.


PHONOLITE
LIMESTONE FLATS
LIMESTONE
LIMESTONE
LINE OF PHONOLITE TALUS

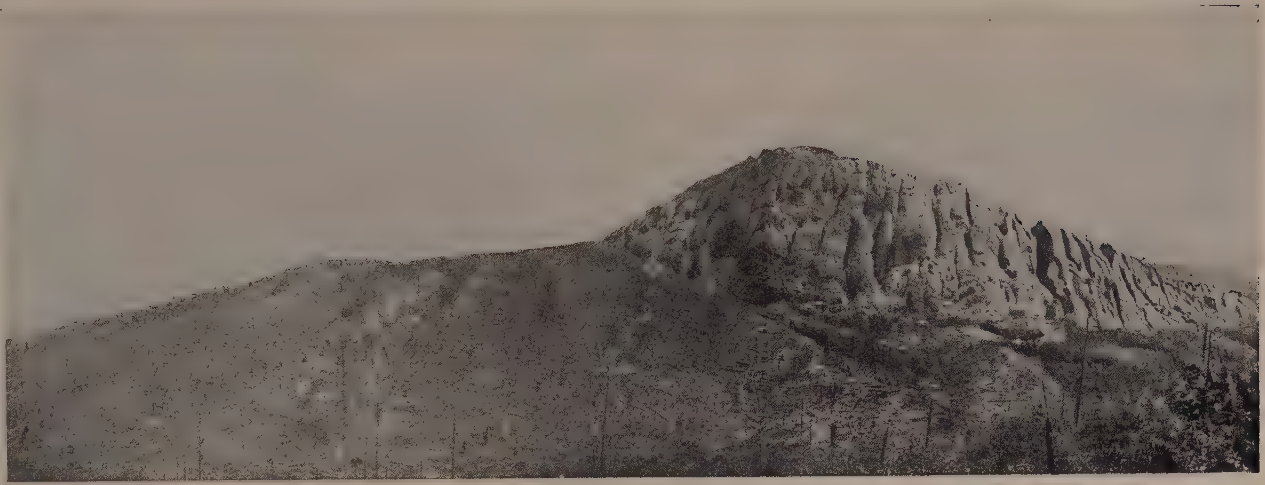
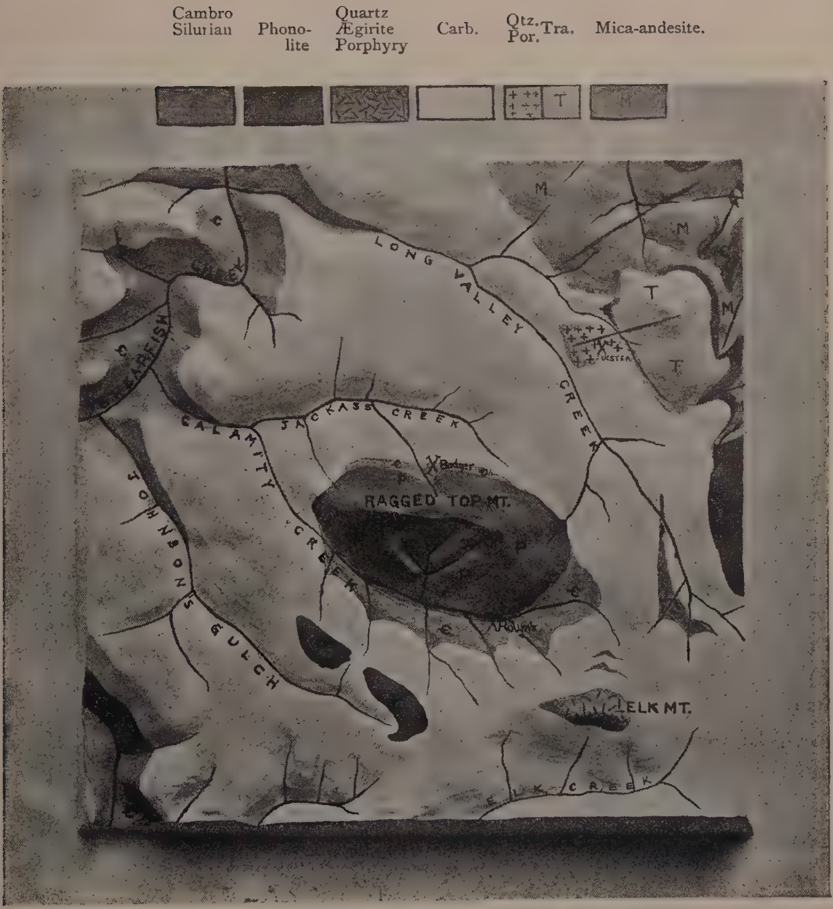


PLATE XIII.

PLATE XIII.

BLACK HILLS GEOLOGY.

Model of Ragged Top Mountain and vicinity to show relations of intrusions to geological formations.


Cambro Silurian
Phonolite
Quartz Ægirite Porphyry
Carb.
Qtz. Por.
Tra.
Mica-andesite.
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C
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CREEK
SPEARFISH
LONG VALLEY CREEK
JACKASS CREEK
CALAMITY CREEK
JOHNSONS GULCH
Ulster
C
Badger
P
RAGGED TOP MT.
P
P
C
C
Rounds
ELK MT.
ELK CREEK

PLATE XIV.

PLATE XIV.

BLACK HILLS GEOLOGY.

Wall of quartz-ægirite-porphyry along the Burlington and Missouri River R. R. to the southwest of Terry Station.

See page 252.

PLATE XIV.

PLATE XV.

PLATE XV.

BLACK HILLS GEOLOGY.

A very irregular intrusion of porphyry in the thin-bedded shales of the Cambrian, on the Burlington and Missouri River R. R. near Portland.

See page 236.

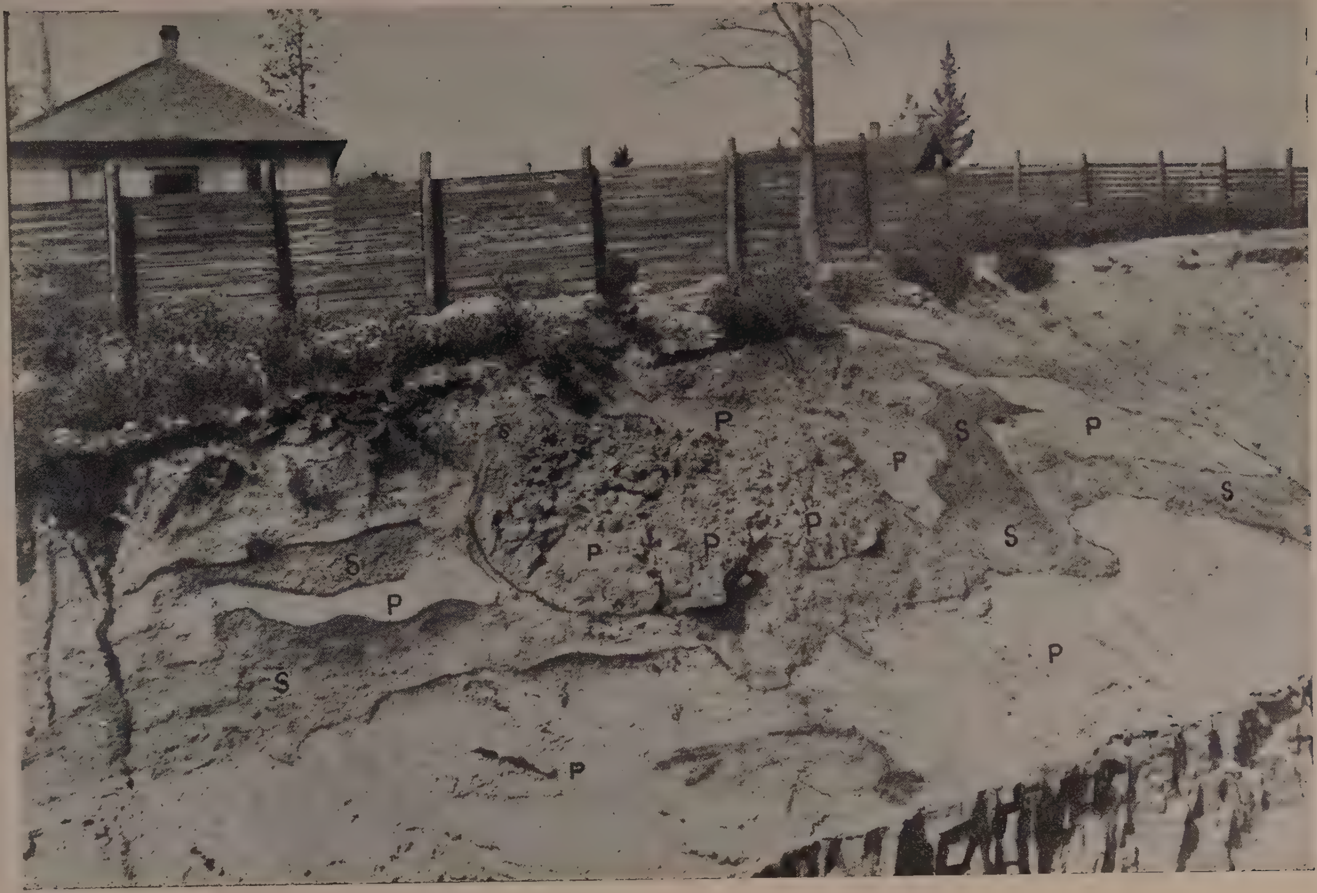
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PLATE XVI.

PLATE XVI.

BLACK HILLS GEOLOGY.

Quartz porphyry from White-Tail Gulch showing "schlieren" or flow lines of more finely grained material.
See page 280.

[ANNALS N.Y. ACAD. SCI., Vol. XII, No. 10, pp. 341 to 478, April 3, 1900.]

THE POSITIONS AND PROPER MOTIONS
OF THE
PRINCIPAL STARS
IN THE
CLUSTER OF COMA BERENICES

AS DEDUCED FROM MEASUREMENTS OF THE RUTHERFURD PHOTOGRAPHS.

WALTER C. KRETZ, PH.D.

(Read April 10, 1899.)

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PART I.

CATALOGUE POSITIONS OF THE STANDARD STARS.

I. Catalogues and Weights.

For the reduction of stellar photographs it is necessary that the positions of certain stars on the plate be known as accurately as possible. Such stars are designated in the following as standards. When I undertook the measurement and reduction of the Rutherfurd Photographs of the Cluster in Coma Berenices, the problem arose to determine such standards.

There was no sufficiently accurate set of meridian observations available. Chase's triangulation of the cluster, made at the Yale Observatory, 1891–1892,[1] includes a number of my stars, and these I might have used as standards. But results obtained by the heliometer are not always reliable; that is to say, although the relative positions are in general very accurate, the group as a whole may show a large systematic error. This was to be feared in the present case, as the absolute positions of the stars of the cluster were made to depend ultimately on but two points, determined by meridian observations. Aside from this consideration, Chase gives a very good authority from which to obtain the proper motions of those stars common both to his work and to the Rutherfurd photographs. Motion of the group as a whole would, however, be eliminated, were his star places employed in the reduction of the plate-measurements. I decided, therefore, to obtain the positions of as many stars as possible from all the catalogues available to me, and to use these as standards, that being the method commonly regarded as leading to the most accurate results. How this assumption was borne out in the progress of the work will be shown later (Part II, Sect. IV). The list of catalogues examined includes all that may claim any confidence mentioned in Knobel's memoir,[1] besides all important modern ones, and I have attempted to make it practically complete. Twelve stars were thus found sufficiently well determined to warrant their reduction. One of these was subsequently rejected as standard, the remaining eleven being finally retained. I shall give, however, a record of all observations of stars in my zone which I found in the catalogues.

---

[1] "Triangulation of the Principal Stars of the Cluster in Coma Berenices," by Frederic L. Chase. Transactions of the Astronomical Observatory of Yale University. Referred to as *Chase*.

List of Catalogues Used.—Of the catalogues examined, the following contained observations of stars present on the plates:

(1) BRADLEY, 1755. Neue Reduction des Bradley'schen Beobachtungen aus den Jahren 1750 bis 1762 von Arthur Auwers. St. Petersburg, 1888.

(2) PIAZZI, 1800. Præcipuarum Stellarum inerrantium Positiones Mediæ * * * ex observationibus habitis * * * ab anno 1792 ad annum 1813. Panormi, 1814.

The dates were obtained from the original observations in the Storia Celeste; they are however very doubtful, as in almost every case more observations were found than agreed with the number given in the catalogue, with no way to determine which were excluded from the final reduction. The mean date of all observations was therefore taken; but in assigning weights the argument used was the number of observations as given in the catalogue.

(3) LALANDE, 1800. Histoire Céleste Française, Tome I. Paris, 1801.

Baily's "Lalande," published by the British Association in 1847, was used only as an index to the zone observations, which were reduced to 1800 by Von Asten's "Neue Hülfstafeln zur Reduction der in der Histoire Céleste enthaltenen Beobachtungen," Vierteljahrsschrift der Astronomischen Gesellschaft, appendix to Vol. 4. Account was taken of the errata published in the introduction to the Paris catalogues, by Peters, and by others.

---

[1] Knobel, "The Chronology of Star Catalogues," in Memoirs of the Royal Ast. Soc., Vol. 43, p. 1.

(4) D'AGELET, 1800. Reduction of the Observations of Fixed Stars made by Joseph Lepaute d'Agelet * * * with a catalogue * * * by B. A. Gould. Washington, 1866.

The mean of the separate observations given in the catalogue was used.

(5) BESSEL, 1825. Astronomische Beobaçhtungen auf der Königlichen Universitäts-Sternwarte zu Königsberg, for the years 1821 to 1833.

Weisse's Catalogue of Bessel's Northern Zones was used only as index to the original observations, which were reduced anew by the aid of Luther's tables in "Astronomishe Beobachtungen auf der Königlichen Universitäts-Sternwarte zu Königsberg," Abt. 37, 2$^{\text{ter}}$ Teil. An explanation of the necessary formulæ there given, which are similar to those in use with Von Asten's tables, will be found in Argelander's Bonner Beobachtungen, Vol. I, p. xxxvi. Account was taken of the errata to the zones recorded in Part I of the volume containing Luther's paper. The star numbers in the Tables, Sect. III of the present paper, are those of Weisse's catalogue.

(6) STRUVE, 1830. Stellarum Fixarum * * * Positiones Mediæ pro epocha 1830 * * * ex observationibus * * * annis 1822 ad 1843. Petropoli, 1852.

Positions were taken from the "Catalogus Generalis" beginning on page 235, and the mean date was used as there given in column nine, unless a B was found in that column. This means that a certain proper motion, deduced from comparisons with Bradley, was included in the reduction, but as its value is not given, it was deemed best, in such cases, to take the star's position directly from a "Catalogus Specialis" in the preceding part of the volume. Reference to the page will in general be found in column eleven of the "Catalogus Generalis." The "Correctiones Ultimæ" given on pp. 360 ff. were not applied in such cases.

(7) POND, 1830. A Catalogue of 1112 Stars * * * from Observations made at * * * Greenwich from the years 1816 to 1833. London, 1833.

The mean date of observation is not given in the catalogue. It was obtained from the original records, published in the "Annual Results of Observations at Greenwich." All observations of small stars were made in the years 1830 to 1833 incl. ; those of principal stars in right ascension from 1816 to 1833, and in north polar distance from 1826 to 1833. There are, in general, two observations in N. P. D. for each day, one with each of the two mural circles. For one star (No. 501, decl.), more observations were found in the annual results than are counted in the catalogue ; the same rule with regard to the weight and the mean date was followed in this case as in that of Piazzi.

(8) TAYLOR, 1835. A General Catalogue of the Principal Fixed Stars from Observations made * * * at Madras in the years 1830 to 1843. Madras, 1844.

The mean date is not given. It was obtained from the original records in Vol's 1 to 5 of the Madras observations in a manner similar to that explained by Argelander on pp. 18 and 19 of Vol. VII, Bonner Beobachtungen ; remembering however, that according to the introduction to Vol. 3, the transit instrument was down from 1834 March 6th to 1835 Jan. 31st, and that Taylor was absent in England in the years 1840 and 1841. Account was also taken of the fact that the constellation Coma Berenices comes to the meridian before midnight in the early part of the year. The star numbers as printed in this paper were corrected according to the errata, pp. 6–8, of the catalogue.

(9) RÜMKER, 1836. Mittlere Oerter von 12,000 Fixsternen * * * aus den Beobachtungen auf der Hamburger Sternwarte * * * Hamburg, 1852.

The mean date was taken as 1841, in accordance with the note given by Schorr in his "Bemerkungen zu Carl Rümkers Sterncatalogen," Mitteilungen der Hamburger Sternwarte, No. 3, p. 6.

(10) ROBINSON, 1840. Places of 5,345 Stars observed from 1828 to 1854 at the Armagh Observatory. Dublin, 1859.

The mean date was obtained from the record of the separate observations printed in the first part of the volume.

(11) GILLISS, 1840. Catalogue of 1248 Stars observed at Washington between October, 1838 and July, 1842 * * * Washington, 1846.

The mean date was obtained from the annual results given in the same volume.

(12) PARIS$_1$, 1845. Catalogue de l'Observatoire de Paris. Étoiles observées aux Instruments Méridiens de 1837 à 1853. Vol. 3, Paris, 1896.

(13) JACOB, 1850. A Subsidiary Catalogue of 1440 Stars * * * from observations made at Madras in the years 1849–1853. Madras, 1854.

Positions from this catalogue were kindly furnished in manuscript by Prof. Pickering.

(14) WROTTESLEY, 1850. A Catalogue of the Right Ascensions of 1009 Stars; in Mem. Roy. Astr. Society, Vol. XXIII, p. 1. London, 1854.

(15) SIX-YEAR, 1850. Catalogue of 1576 Stars formed from the observations made during Six Years, from 1848 to 1853 at * * * Greenwich. London, 1856.

(16) POULKOVA, 1855. Positions Moyennes déduites des observations faites * * * 1840–1869. Observations de Poulkova, Vol. VIII. St. Pétersbourg, 1889.

The number of observations is not given in the catalogue. It was obtained from the Vols. VI and VII of the "Observations de Poulkova."

(17) ARGELANDER, 1855. Mittlere Oerter von 33,811 Sternen, abgeleitet aus den * * * in den Jahren 1845–1862 angestellten Beobachtungen. Bonn, 1867.

(18) SEVEN-YEAR, 1860. Seven-Year Catalogue of 2,022 Stars deduced from Observations extending from 1854 to 1860 at * * * Greenwich. London, 1864.

(19) PARIS$_2$, 1860. Catalogue de l'Observatoire de Paris. Étoiles observées aux Instruments Méridiens de 1854 à 1867. Vol. 3, Paris, 1896.

(20) YARNALL, 1860. Catalogue of Stars observed at the United States Naval Observatory during the years 1845 to 1877. Third edition, revised * * * by Professor Edward Frisby. Washington, 1889.

(21) BRUXELLES, 1865. Catalogue de 10,792 Étoiles observées * * * de 1857 à 1878 * * * par Ernest Quetelet. Bruxelles, 1887.

The catalogue itself does not include positions of the fundamental stars determined at this observatory. They are given in a separate list on pp. xv ff. of the same volume. None of my stars was found among them.

(22) SAFFORD, 1865. Observations in Right Ascension of 505 Stars, being Vol. IV, Pt. II of the Annals of Harvard College Observatory. Cambridge, 1878.

The positions as used were taken from pp. 30–108, where they are given uncorrected for proper motion, and, in the case of ephemeris stars, with certain periodic terms neglected (cf. Introd , p. ix). They are repeated, with these corrections applied, in the General Catalogue on pp. 109–120. In each case, however, the amount of the correction, with its proper sign, is set down in column 9, under the head $\Delta\alpha$ (Introd. p. xv).

(23) NINE-YEAR, 1872. Nine-Year Catalogue of 2,263 Stars deduced from observations extending from 1868 to 1876, made at * * * Greenwich. (No date, Appendix to Observations for 1876.)

(24) DREYER, 1875. Second Armagh Catalogue of 3,300 stars * * * from observations * * * during the years 1859 to 1883 * * * Dublin, 1886.

(25) ROMBERG, 1875. Catalog von 5,634 Sternen aus den Beobachtungen am Pulkowaer Meridiankreise während der Jahre 1874–1880 * * * St. Petersburg, 1891.

(26) PARIS$_3$, 1875. Catalogue de l'Observatoire de Paris. Étoiles observées aux Instruments Méridiens de 1868 à 1881. Vol. 3, Paris, 1896.

Catalogues no. (12), (19), and (26) appear as one work of four volumes, each volume embracing six hours of right ascension for all of the three epochs, 1845, '60, and '75. The three corresponding quantities for each star will always be found together on the same line.

(27) ROGERS, 1875. Catalogue of 1213 Stars observed during the years 1870 to 1879, being Vol. XV, Part I of the Annals of the Astronomical Observatory of Harvard College. Cambridge, 1886.

(28) RESPIGHI, 1875. Catalogo delle Declinazioni medie * * * di 1463 Stelle comprese fra i paralleli 20° e 64° nord * * * in Vol. VIII, Ser. 3, Reale Accademia dei Lincei, 1879–80. Roma, 1880.

(29) CATALOG DER ASTRONOMISCHEN GESELLSCHAFT, Zone IX. Catalogue of 14,464 Stars between 24° 15′ and 30° 57′ North Declination, 1855 * * * by A. Graham. Leipzig, 1897.

(30) TEN–YEAR, 1880. Ten-Year Catalogue of 4,059 Stars deduced from observations extending from 1877 to 1886 at * * * Greenwich. London, 1889.

Annual results reduced to the beginning of the year of observation, but as yet uncombined to form larger catalogues, were used in exactly the same manner as were the preceding works. The following series were found to contain observations of my stars.

(31) CAMBRIDGE YEARLY RESULTS, 1836–1869. Astronomical observations made at the Observatory of Cambridge in the years 1836 to 1869.

The stars in these lists are not numbered. The mean date was obtained from the separate results preceding the Catalogue. The same remarks apply to no. (32).

(32) EDINBURGH YEARLY RESULTS, 1840–1886. Astronomical Observations made at the Royal Observatory, Edinburgh, from 1840 to 1886.

Observations were taken at Edinburgh previous to 1840 by Henderson. They were reduced under his direction, while those taken after 1840 were reduced by C. P. Smyth. The earlier set being entitled to higher weight than the latter, I have not grouped them both under one heading. None of my stars was found in the earlier series. The Catalogue compiled from all of these observations by Smyth, under the title "Star Catalogue, Discussion, and Ephemeris from 1830 to 1890" was used only as index to the yearly records.

(33) RADCLIFFE YEARLY RESULTS, 1862–1879. Results of Astronomical Observations made at the Radcliffe Observatory in the years 1862 to 1879.

No observations of stars were made in 1877, '78, and '79.

(34) MADRAS YEARLY RESULTS, 1862–1882. Results of Observations of the fixed stars made at Madras in the years 1862 to 1882 inclusive, under the direction of N. R. Pogson.

(35) GREENWICH YEARLY RESULTS, 1887 to 1894. Results of the Astronomical Observations made at the Royal Observatory, Greenwich, in the years 1887 to 1894.

The Greenwich Five-Year Catalogue includes some of these observations ; but the greater part of them are not as yet combined. Such of my stars as were found in this series were of the latter number.

Weights : On the preceding pages I have detailed the catalogues used in the present paper. The observations are, of course, not all of the same standard of excellence. Weights were assigned depending approximately on the probable error of a position as given in a catalogue, the probable error of an observation of unit weight being taken arbitrarily as $0''.4$ of arc of a great circle. A table of weights was constructed on this basis by Dr. Davis when engaged in a research similar to the present one, and is printed in his memoir on the subject.[1] To it I refer. It must be remembered, however, in regard to the Annual Results, that I have regarded the observations of each year as forming a separate catalogue, and have weighted them as such, whereas Dr. Davis first reduced them all to 1875, and then assigned a weight to the mean depending on the total number of observations taken at the observatory in question. In all other respects the table was used exactly as there explained.

A few of the catalogues used by me are not included in this list. They follow, together with the number of the star or stars, the corresponding number of observations, and the assigned weight. The figures in brackets refer to the preceding list of catalogues.

(11) GILLISS, 1840. Star no. 605, 1 obs., wt. = 0.1.
Star no. 608, 13 obs., wt. = 1.0.
(14) WROTTESLEY, 1850. Star no. 447, 5 obs., wt. = 0.5.
(22) SAFFORD, 1865. Star no. 194, 7 obs., wt. = 2.0.
Star no. 195, 6 obs., wt. = 2.0.

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[1] "Declinations and Proper Motions of Fifty-Six Stars," by Herman S. Davis, Ph.D. Memoir I, of the N. Y. Academy of Sciences. Referred to as *Davis*. The table of weights will be found on pp. 14 to 18.

For (17) ARGELANDER, 1855, the same weights were used as are given for Oeltzen-Argelander in *Davis*.

The same table was assumed to apply to both right ascensions and declinations. This has been the generally accepted method: but my results indicate that it is not always correct. On the whole, the residuals are larger in right ascension than in declination. Especially is this the case with the older catalogues. I have compared the probable errors in the two coördinates obtained from the eight published zones of the A. G. C. (that being my standard of weight) and find a difference, which, though slight, is in the direction mentioned. A separate table of weights to be used for right ascensions would therefore be desirable. For my purpose, I have not deemed the additional accuracy obtained thereby sufficient to compensate for the labor involved.

II. Method of Reduction.

Precession.—The epoch selected was 1875, that being very near the mean of the dates at which the plates were taken. The precession factors were computed by Professor Hill's formulæ as given in the "*Star Tables of the American Ephemeris,*" Wash., 1869, pp. xviii, xix. The constants used were those of Peters and Struve, being, for 1800

$$m = 3^{s}.07082 + {}^{s}.000\,01899t$$
$$n = 20''.0607 - {}''.000\,0863t.$$

Introducing these values in Hill's formulæ, we obtain for 1875, the numbers in brackets denoting logarithms :

$$\frac{d\alpha}{dt} = 3^{s}.07225 + [0.126115] \sin\alpha \tan\delta + \mu$$

$$\frac{d\delta}{dt} = [1.302206] \cos\alpha + \mu'$$

$$\begin{aligned}\frac{d^2\alpha}{dt^2} = {} & [4.63380_n - 10] \left(\frac{d\alpha}{dt} - \mu\right) \\ & + [5.98778 - 10]\left(\frac{d\alpha}{dt} + \mu\right) \cos\alpha \tan\delta \\ & + [4.81169 - 10]\left(\frac{d\delta}{dt} + \mu'\right) \sin\alpha \sec^2\delta \\ & + [4.9866 - 10]\, \mu\mu' \tan\delta \\ & + 0.^{s}000\,032\,210\end{aligned}$$

$$\begin{aligned}\frac{d^2\delta}{dt^2} = {} & [4.63380_n - 10]\left(\frac{d\delta}{dt} - \mu'\right) \\ & + [7.16387_n - 10]\left(\frac{d\alpha}{dt} + \mu\right) \sin\alpha \\ & + [6.7367_n - 10]\, \mu^2 \sin 2\delta.\end{aligned}$$

The third term, both in right ascension and in declination, was taken from Kloock's "*Tafeln der Praecession,*" that being sufficiently accurate on account of the small value of the proper motion for all of my stars.

In the above formulæ, a, μ, δ and μ' denote respectively the right ascension and corresponding proper motion and the declination and corresponding proper motion for 1875. In calculating the constants, the right ascensions and declinations were taken uniformly from the Astronomische Gesellschaft Catalog, Zone IX; the proper motions either from Auwers' "*Neue Reduction der Bradley'schen Beobachtungen*" or from Safford's "*Catalogue of Mean Declination of 2,018 Stars.*"

If now we put

$$J=\frac{da}{dt}, \quad K=\frac{d^2a}{dt^2}\times 10^2, \quad P=\frac{d^3a}{dt^3}\times\tfrac{1}{6}\times 10^6$$

$$L=\frac{d\delta}{dt}, \quad M=\frac{d^2\delta}{dt^2}\times 10^2, \quad N=\frac{d^3\delta}{dt^3}\times\tfrac{1}{6}\times 10^6$$

and let

T = the epoch of any catalogue, and

a_T, δ_T = the right ascension and declination as there given, then will

$$a_{1875}=a_T+J(1875-T)+K\frac{-(1875-T)^2}{200}+P\left(\frac{1875-T}{100}\right)^3$$

$$\delta_{1875}=\delta_T+L\,(1875-T)+M\frac{-(1875-T)^2}{200}+N\left(\frac{1875-T}{100}\right)^3$$

as is evident at once when we remember that the above expressions are the first few terms of the expansion by Taylor's formula of a and δ, thus

$$a=a_0+\left(\frac{da}{dt}\right)t+\tfrac{1}{2}\left(\frac{d^2a}{dt^2}\right)t^2+\tfrac{1}{6}\left(\frac{d^3a}{dt^3}\right)t^3+\ldots$$

and similarly for δ. Here a_0 is the right ascension at the epoch for which the precession is to be computed, 1875 in the present case, and t is the interval from this epoch to the epoch of a. For dates later than 1875, t is plus; for those earlier, it is minus. Hence, transposing a_0 to the first, and a to the second member, changing the signs and introducing the previous notation, we obtain the series in the form given above.

The coefficients of *J*, *K* and *P*, denoted respectively by *U*, *V*, and *W*, depend only on the time, and may be tabulated. This is here done for the epochs used by me. Signs at the top are for the dates at the left of the table; signs at the bottom are for dates at the right.

Epoch.	*U*	*V*	*W*		Epoch.	*U*	*V*	*W*	
	+	−	+			+	−	+	
1755	120	72.000	1.728		1860	15	1.125	0.003	1890
1800	75	28.125	0.422		61	14	0.980	0.003	89
24	51	13.005	0.133		62	13	0.845	0.002	88
25	50	12.500	0.125		63	12	0.720	0.002	87
30	45	10.125	0.091		64	11	0.605	0.001	86
1835	40	8.000	0.064		1865	10	0.500	0.001	1885
36	39	7.605	0.059		66	9	0.405	0.001	84
40	35	6.125	0.043		67	8	0.320	0.001	83
42	33	5.445	0.036		68	7	0.245	0.000	82
43	32	5.120	0.033		69	6	0.180		81
1844	31	4.805	0.030		1870	5	0.125		1880
45	30	4.500	0.027		71	4	0.080		79
47	28	3.920	0.022		72	3	0.045		78
50	25	3.125	0.016	1900	73	2	0.020		77
55	20	2.000	0.008	1895	74	1	0.005		76
1856	19	1.805	0.007	1894	1875	0	0.000		1875
58	17	1.445	0.005	92					
59	16	1.280	0.004	91					
	−	−	−	Epoch.		−	−	−	Epoch.

Proper Motion.—Some catalogues take account of the proper motion in reducing from apparent to mean place. As its value, however, in general differs from that assumed in the present paper, a correction to eliminate its effect must be introduced. μ being the proper motion as assumed by me, μ' that used in the catalogue under consideration, and T and t, as usual, the epoch of reduction and the epoch of the catalogue respectively, we have

$$\text{Correction for erroneous } pm = (T - t)(\mu - \mu'),$$

which becomes, for $\mu' = 0$

$$(T - t)\mu.$$

It is not always plain whether a certain catalogue uses proper motion in the reduction to mean place or not. I subjoin the conclusion at which I arrived in each special case, and in accordance with which the correction was applied in the succeeding calculations. The numbers refer to the catalogues detailed in Sec. I.

(1) The proper motion given is used in the reduction. See pp. 18 and 20 of the introduction.

(2), (3), (4), (5) These do not take account of proper motion. In (3) and (5) it is not mentioned; in the case of (4) see Introd., p. 26, § 11; and for (2) see Argelander's Bonner Beobachtungen, Vol. VII, p. 10.

(6) No proper motion is applied unless a *B* is found in the column headed "Epocha Media." Its value, although not given, may be obtained from the value for Str.—Bradley, given pp. 299 ff. See Introd., p. LXXX.

(7) Pond uses the A. S. C. constants and no proper motion unless therein included. Such cases are marked by an asterisk in the column of precessions, the same as in the volumes from which the constants are copied.

(8) Proper motions greater than 0''.5 are always, and those greater than 0''.25 are sometimes included in the reduction. Smaller values are always neglected. Introd., p. 2.

(9) No statement. Proper motion is probably not taken into account.

(10) According to Introd., p. xxviii, proper motion is not used in the reductions.

(11) Proper motion is neglected in reducing the observations to the beginning of the year, except where included in the A. S. C. constants (Introd., p. XXIV); but in combining the separate annual results into a general catalogue, it is taken into account (p. 595, "Column 6") whenever its value is given.

(12) See (26).

(13) This catalogue does not take account of proper motion. As it was not accessible to me, I could not personally verify the above statement, which is made in accordance with *Davis*, p. 28, no. 69.

(14) I could not find any definite statement bearing on

the point in question. It seems, however, that proper motion is not used. Cf. Introd., pp. 15–17.

(15) The same notes apply to this catalogue as to no. (11), except in the case of N. A. stars, when the proper motion is taken into account. See Introd., p. iv; also Twelve-Year Catalogue, pp. vii and ix, and Seven-Year Catalogue for 1860, pp. {vi} and {x}, and Appendix.

(16) No statement is made in the introduction to Vol. VIII of the "Observations de Poulkova," which contains the catalogue. Backlund, however, in an article designed originally to form the preface to the catalogue, but afterwards published in the Memoirs of the St. Petersburg Imperial Academy, states, that proper motion was used when given either by Auwers in his "*Bradley*" or by Argelander in his "*250 Stars with Proper Motions*." Backlund superintended most of the computations. Loc. cit., Vol. 34, no. 7, p. 4.

(17) Proper motion seems to be neglected. No mention of this matter is made in the introduction.

(18) Proper motion is used in the reductions. See Introduction, pp. {vi} and {x}.

(19) See (26).

(20), (21) Both catalogues neglect proper motion. See (20) Introd., p. XXIV; (21) Introd., p. XII.

(22) See the remarks on this catalogue in Sec. I of the present paper.

(23) Proper motion is used. See Introd., p. 4.

(24) This catalogue does not take account of proper motion. Cf. Introd., p. ix.

(25) The proper motion as given is included in the reductions. See Introd., p. (12).

(26), (12), and (19) According to p. [2] of Vol. I, proper motion is always neglected.

(27) Account is taken of the proper motion whenever given. Introd., p. vi.

(28) Proper motion is included in the annual variation for each star given in this catalogue. Its value, although not set down, may be obtained by subtracting the corresponding

geometric precession from that quantity. The original authority for the proper motions of all others than fundamental stars is the B. A. C. See p. 134.

(29) Proper motion is not used.

(30) As in the other Greenwich catalogues, proper motion is employed in the reductions. See Introd., p. 4.

In the case of the Annual Results, proper motion has a very slight effect as it is always used for a fraction of a year only, and is therefore rather unimportant. I found, however, the following:

(31) The Cambridge Annuals. Proper motion is not taken into account, except for Nautical Almanac Stars when included in the annual variations there given.

(32) The Edinburgh Annuals, up to the publication of the B. A. C. in the year 1845, were reduced by means of the A. S. C. and Nautical Almanac constants, using proper motion only if therein included. After that, however, the B. A. C. values, both of precession and proper motion, were always used, if possible, for stars not given in the N. A.

(33) The Radcliffe Annuals do not use proper motion. For Nautical Almanac Stars it is, however, generally included in the precessions; these are marked with an asterisk in such cases.

(34) The Madras Annuals do not use proper motion.

(35) The Greenwich Annuals employ proper motion in the reduction to mean place.

Systematic Corrections.—The system used throughout was that of the "*Fundamental-Catalog der Astronomischen Gesellschaft.*" Corrections to reduce the catalogue positions to this standard are given by Auwers in the Astronomische Nachrichten nos. 3195–96, and 3413–14. A number of lists of stars, notably annual results, are not mentioned in these papers, however. For such cases it was generally possible to obtain values of the corrections to the declinations from Boss, "*Report on the Declination of Stars, etc.,*" pp. 579 ff. They were reduced from his "mean system" to the A. G. C. system by the aid of the formulæ and table following, which I reproduce from Dr. Davis' memoir:

To Boss' value add the quantity

$$m + K(T - 1883) \text{ when } T < 1866$$

or

$$m + K'(T - 1883) \text{ when } T > 1866.$$

Here

$$m = \text{A. G. C.} - \text{Boss (good for 1883)}$$

and is obtained from the Berlin Jahrbuch, 1884, Appendix. K and K' are the annual variations of m computed as shown in the table, p. 359, in which we assume $\Delta\delta_a = 0$.

There still remained a number of cases to be treated, however, chiefly right ascensions, for Boss gives corrections to the declinations only. For all of these I deduced corrections by direct comparison with some suitable catalogue whose system was well known. The labor was greatly simplified by the fact, that no account had to be taken of change in right ascension or in declination, as my stars are all situated within a few degrees of each other. The rule laid down was to compare as many stars as possible (usually about 12) within not more than one hour in right ascension, and five degrees in declination on either side of the center of my plate. Systematic corrections were thus deduced for the following catalogues:

Bessel ((5) of Sect. I), *Zones 464 and 503.*—Auwers, in his zone of the A. G. C., gives corrections to all those of Bessel's zones which fall within the limits of his catalogue. He shows that they consist of two parts, a systematic one, depending on the constants used in the reductions, and one due purely to accidental causes. Luther's tables fail to eliminate the latter class. Without attempting to distinguish between them, I deduced the total amount by direct comparison with the A. G. C., correcting for proper motion whenever that was possible. I find thus:

A. G. C.—Bessel, Zone 464 (in α) $= + 0^{s}.190$
" " " " (in δ) $= - 3''.60$

A. G. C.—Bessel, Zone 503 (in α) $= + 0^{s}.122$
" " " " (in δ) $= + 3''.15$

TABLE.

δ	A. G. C.—Boss for					A. G. C.—Boss for		Annual Variation.			
	Groom. 1810	Struve. 1830	Abo 1830	Mean 1823 a	Mean 1830 b	Poulkova 1855 c	(Auwers) 1883 m	Note 1.	Note 2.	1810 to 1865 K	1866 to 1883 K′
	″	″	″	″		″	″				
65°	+0.38	+0.28	+0.25	+0 30		+0.21	+0.03	—0.0045	—0.0011	—0.0028	—0.0064
60	+ .18	+ .18	+ .18	+ 18		+ .15	+ .04	— .0023		— .0001	— .0039
55	+ .06	+ .06	+ .06	+ .06		+ .01	+ .06	+ .0000	+ .0050	+ .0025	+ .0018
50	+ .09	— .14	— .08	— .04		— .05	+ .11	+ .0026		+ .0039	+ .0057
45	+ .01	— .29	— .23	— .17		— .02	+ .15	+ .0053	+ .0053	+ .0053	+ .0061
40	[— .50]	— .54	— .52		″ —0.53	— .19	+ .15	+ .0128		+ .0121	+ .0121
35		— .72	— .69		— .71	— .26	+ .14	+ .0160	+ .0174	+ .0167	+ .0143
30		— .84	— .76		— .80	— .19	+ .09	+ .0168		+ .0157	+ .0100
25		— .95	— .81		— .88	— .13	+ .01	+ .0168	+ .0116	+ .0142	+ .0050
20		—1.01	— .92		— .97	— .07	— .06	+ .0173		+ .0147	+ .0004
15		—0.95	— .83		— .89	— .02	— .10	+ .0149	+ .0126	+ .0138	— .0029

NOTE 1.—This column gives $\frac{a-m}{1823-1883}$ or $\frac{b-m}{1830-1883}$ as the case may be.

NOTE 2.—This is an approximate annual variation deduced by direct comparison of the proper motions of Boss and AUWERS by Professor T. H. Safford.

K is the mean of the two preceding columns and $K' = \frac{c-m}{1855-1883}$.

Cambridge Annuals (31).—Observations in right ascension of my stars were taken in the years 1842, '44, '45 and '47. Corrections to the years 1842 and 1845 were obtained by direct comparison with Struve's "Positiones Mediae." During 1844 and 1847 not enough stars were observed in the zone selected by me to warrant a comparison with Struve. For 1844 I accordingly assumed the same corrections as for 1845, and for 1847, zero was used, as no other value was procurable. Corrections to the declinations are given by Boss. My investigations give, for the right ascensions:

A. G. C.—Cambridge 1842 = $-0^s.075$
A. G. C.—Cambridge 1845 = $+0^s.147$

Edinburgh Annuals (32).—Boss, who gives corrections to the declinations, divides this series into several groups, of which the following include the dates of observation of my stars: 1854–1860, 1861–1864, 1865–1869. Corrections were computed by comparison with the A. G. C. for the years 1856, 1864, and 1868, being one year in each group. Two stars were observed in 1842, and for this year a correction was deduced by comparison with the new Seven-Year Catalogue. The reductions were always made including proper motion if possible. The values found were as follows:

A. G. C.—Edinb. 1842 = $-0^s.012$
A. G. C.—Edinb. 1856 = $-0^s.087$
A. G. C.—Edinb. 1864 = $-0^s.070$
A. G. C.—Edinb. 1868 = $-0^s.042$

Radcliffe Annuals (33).—Corrections to the declinations observed before 1874 are given by Boss. One of my stars was found in the volume for 1874. The correction in this case was calculated by extrapolation from 1872 and 1873. For the right ascensions the usual method was followed, comparisons being made both with the A. G. C. and with the Paris 1875. Corrections to the observations of the years 1868, 1870 and 1871 were thus obtained. In the year 1873 not sufficient stars were observed to make a satisfactory comparison possible. For this case, zero was therefore assumed. The results reached were as follows:

A. G. C.—Radcliffe 1868 = + $0^s.033$
A. G. C.—Radcliffe 1870 = — $0^s.071$
A. G. C.—Radcliffe 1871 = — $0^s.020$

Greenwich Annuals (35).—The same systematic corrections were used as are given by Auwers for the Ten-Year Catalogue. See *Davis*, p. 24, no. 40.

A few of the catalogues deserve special notice in this connection. They are:

(1) *Auwers-Bradley.*—No systematic corrections to this catalogue have been published by the author, which indicates that their value is zero. I have so assumed it for the two stars found in this list.

(4) *d'Agelet.*—Auwers gives systematic corrections to this catalogue on p. 60 of his zone of the A. G. C., but applying only within the limits of that zone. On page 30 of the introduction, Gould himself gives the result of a comparison with Piazzi. His terms are not quite clear, however. He gives corrections for what he calls the first and second group, without stating where the dividing line between the groups is situated. I have assumed it to be at 12^h in accordance with a statement at the bottom of page 29, and find thus

Piazzi—d'Agelet in α = + $0^s.079$
Piazzi—d'Agelet in δ = + $1''.22$,

whence (A. G. C.—d'Agelet) is easily obtained.

(6) *Struve.*—The same correction was assumed to apply to the "Catalogus Specialis" for 1824 as to the "Catalogus Generalis" for 1830.

(17) *Argelander.*—In accordance with pp. vi and ix of the introduction, the corrections of the Abo Catalogue reduced to 1855, as given by Auwers, were applied to my stars found in this catalogue.

(12), (19), and (26) *Paris.*—The corrections given by Auwers for the first twelve hours of right ascension were assumed to apply equally to the third quadrant.

(20) *Yarnall.*—Corrections to this catalogue will be found in both of Auwers' papers. The second set was used by me.

Formulæ for Adjustment.—The usual methods of least-square solution with artifices of computation analogous to those published in *Davis*, pages 11 and 12, were employed. I shall deduce the formulæ for right ascension only; the discussion for the other coördinate is entirely similar.

If we let

B_i = the seconds of an observed right ascension reduced to 1875, using an assumed value for the proper motion, and corrected for systematic errors;

t_i = the date of observing B_i;

α_0 = the seconds of the right ascension to be obtained from the observations, corresponding to some fixed epoch T_0;

$\Delta\mu_0$ = the correction to be subtracted from the assumed proper motion;

then evidently we should have

$$\alpha_0 - \{B_i + \Delta\mu_0 (t_i - T_0)\} = 0; \tag{1}$$

or, if the weight of B_i be p_i,

$$\sqrt{p_i}\,\alpha_0 - \sqrt{p_i}\,\Delta\mu_0 (t_i - T_0) - \sqrt{p_i}\,B_i = 0. \tag{1a}$$

Writing, then, m equations of condition of the above form, one for each observed B_i, and solving by least squares, we get the following normals, where the square brackets as usual denote summation:

$$\left.\begin{aligned} [p]\,\alpha_0 - [p(t - T_0)]\,\Delta\mu_0 - [pB] &= 0 \\ -[p(t - T_0)]\,\alpha_0 + [p(t - T_0)^2]\,\Delta\mu_0 + [pB(t - T_0)] &= 0. \end{aligned}\right\} \tag{2}$$

By suitably selecting the epoch T_0 we can greatly facilitate the succeeding work—an artifice first employed for this kind of work by Professor Safford.[1] For let us take T_0 as the mean of all the dates t, that is, let

$$T_0 = \frac{[pt]}{[p]},$$

---

[1] See Safford, "Catalogue of 2018 Stars," Introd., p. 12.

then will

$$[p(t-T_0)]=0,$$

and equations (2) become

$$\left.\begin{aligned}&[p]\,a_0-[pB]=0\\&[p(t-T_0)^2]\Delta\mu_0+[pB(t-T_0)]=0,\end{aligned}\right\}\tag{3}$$

whence at once

$$\left.\begin{aligned}&a_0=\frac{[pB]}{[p]}\text{ with the weight }[p]\\&\Delta\mu_0=-\frac{[pB(t-T_0)]}{[p(t-T_0)^2]}\text{ with the weight }[p(t-T_0)^2].\end{aligned}\right\}\tag{4}$$

If now we write

$$(t-T_0)=C,\quad p(t-T_0)=D,$$
$$a_0-B=E,$$

and remember that

$$[pC(a_0-B)]=a_0[pC]-[pCB]=-[p(t-T_0)B]$$

since

$$[pC]=0,$$

we get finally the formulæ

$$\left.\begin{aligned}&a_0=\frac{[pB]}{[p]}\\&\Delta\mu_0=\frac{[DE]}{[CD]}.\end{aligned}\right\}\tag{5}$$

The probable error of an observation B whose weight is unity is, by the usual formula

$$r_1=\pm.6745\sqrt{\frac{[vv]}{m-2}},$$

the v's being the residuals obtained by substituting the final values of a_0 and $\Delta\mu_0$ in equation (1). Hence the probable error of

$$\left.\begin{aligned}&a_0\text{ at the epoch }T_0=\frac{r_1}{\sqrt{[p]}}=r_T\\&\Delta\mu_0=\frac{r_1}{\sqrt{[CD]}}=r_\mu\\&a_0\text{ reduced to 1875 using }\Delta\mu_0=\sqrt{r_T{}^2+\{(1875-T_0)\,r_\mu\}^2}=r_{1875}.\end{aligned}\right\}\tag{6}$$

As $\Delta\mu_0$ and a_0 are not independently determined the correctness of the last formula is not immediately evident. It is, however, easily proved. For we have

$$
\begin{aligned}
a_{1875} &= a_0 + (1875 - T_0)\Delta\mu_0 \\
&= \frac{[pB]}{[p]} - (1875 - T_0)\frac{[pCB]}{[CD]} \qquad \text{[by equation (4)]} \\
&= \frac{p_1B_1 + p_2B_2 + \dots + p_mB_m}{[p]} \\
&\qquad - (1875 - T_0)\frac{p_1C_1B_1 + p_2C_2B_2 + \dots + p_m C_mB_m}{[CD]} \\
&= \frac{1}{[p][CD]}\Big\{p_1 B_1([CD] - (1875 - T_0)[p]C_1) \\
&\qquad + p_2 B_2([CD] - (1875 - T_0)[p]C_2) \\
&\qquad + \dots\dots\dots\Big\}
\end{aligned}
$$

and since the B's are independent, and the probable error of B_i is $r_1 / \sqrt{p_i}$, we get for the probable error of a_{1875}

$$
\begin{aligned}
r^2_{1875} &= \frac{1}{[p]^2[CD]^2}\Big\{p_1 r_1^2([CD] - (1875 - T_0)[p]C_1)^2 \\
&\qquad + p_2 r_1^2([CD] - (1875 - T_0)[p]C_2)^2 \\
&\qquad + \dots\dots\dots\Big\} \\
&= \frac{r_1^2}{[p]^2[CD]^2}\Big\{[p][CD]^2 - 2[CD][p](1875 - T_0)[pC] \\
&\qquad + [p]^2[pC^2](1875 - T_0)^2\Big\} \\
&= \frac{r_1^2}{[p]} + (1875 - T_0)^2\frac{r_1^2}{[CD]} \\
&= r_T^2 + (1875 - T_0)^2 r_\mu^2
\end{aligned}
$$

remembering that

$$[pC] = 0 \text{ and } [pC^2] = [CD].$$

In applying the above formulæ to a special case, I invariably proceeded as follows (the explanation is again confined to right ascension; it applies equally to declination, however):

Calculate the sums

$$\Sigma(pB),\quad \Sigma(pt),\quad \Sigma(p).$$

Then

$$a_0 = \frac{\Sigma(pB)}{\Sigma(p)} - \beta, \qquad T_0 = \frac{\Sigma(pt)}{\Sigma(p)} - \beta',$$

β and β' being the remainders. Now form for each catalogue position the quantities

$$(t - T_0) = C,\quad p(t - T_0) = D,\quad (a_0 - B) = E.$$

The computations up to this point will all be checked,[1] when

$$\Sigma p(a_0 - B) = -\beta, \qquad \Sigma p(t - T_0) = +\beta'.$$

From the expressions last obtained we easily get

$$\Sigma(DE) \text{ and } \Sigma(CD)$$

which we check[1] by the equations

$$\Sigma(DE) = \Sigma(pE \cdot C)$$
$$\Sigma(CD) = \Sigma(pC^2).$$

Then

$$\Delta\mu_0 = \frac{\Sigma(ED)}{\Sigma(CD)}$$

and

$$\mu_0 = \mu - \Delta\mu_0,$$

μ being the previously assumed proper motion. Also

$$a_{1875} = a_0 - \Delta\mu_0\,(1875 - T_0).$$

To obtain the probable errors, I did not, however, employ formulæ (6) as they stand. For thereby the weight of each star is placed on an independent basis, and the probable errors form no means whereby to judge of the relative accuracy of the final positions. For the factor r_1 is not the same for all the stars, depending, as it does, on the accidental error in each catalogue as shown by the residual. We must seek a value for r_1, which will satisfy all the observations taken of all the stars, not of one star only. Such a value is furnished by the statement in Sec. I, "WEIGHTS," which reads, that the probable error of an observation of unit weight was arbitrarily assumed as $0''.4$

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[1] As suggested in *Davis*, page 11.

of arc of a great circle. If then we change formulæ (6) to read

$$r_T = \frac{0''.4}{\sqrt{[p]}}, \quad r_\mu = \frac{0''.4}{\sqrt{[CD]}}$$

and, as before

$$r_{1875} = \sqrt{r_T^2 + \{(1875 - T_0)r_\mu\}^2},$$

we obtain probable errors which make a direct comparison possible, and which enable us to assign relative weights to the resulting positions for 1875. This is what I have done throughout, and all probable errors are computed by the above expressions. It should be mentioned here, however, that, for right ascensions, the values obtained by the above formulæ must be multiplied by sec δ, in order to make them applicable to the position of the star; for evidently the formulæ give the probable error in equatorial seconds for both coördinates. This I have done for all of my stars, and the probable errors in right ascension found in the succeeding tables are therefore in terms of seconds of arc of a small circle of declination passing through the star in question.

III. Tables and Results.

Star-Tables.—On the following pages are recorded the data from which the final positions were obtained, together with the most important part of the calculations. The tables, when taken in connection with the preceding sections, require little comment. A few points may be mentioned, however.

The caption gives the Bonn Durchmusterung number, the usual designation of a star, and Chase's number; also the precession constants, together with the right ascension and declination for 1875, and the respective assumed proper motions used in calculating the same.

Columns 1, 2, 3, 4, 5, 6 and 12 require no explanation. They refer to matters treated in Sect. I of this paper.

Columns 7 to 11 are discussed in Sect. II; column 7 under the head "PROPER MOTION"; column 8 under that of "PRECESSION"; and 10 under that of "SYSTEMATIC CORRECTIONS." Column 9 is the sum of 6, 7, and 8. 11 is explained by the heading.

Column 15 shows the residual of each observation, and 13 and 14 exhibit the computation by which these are derived. This matter has not been treated in detail before, as I deem it rather unimportant for the present purpose. The probable error is not made to depend on the residuals, and they are here recorded merely to give an idea of the interagreement of the observations; they are nowise used in the work. The method is sufficiently explained by the headings; and it is plain that, if carried through as shown, the desired quantities will be obtained, remembering the form of the observation equations (equation (1) of "FORMULÆ FOR ADJUSTMENT," Sect. II).

Results: At the end of each table the results are shown. They are as follows: Column 3 contains T_0; 5 the total number of observations; 6 the coördinate α_0 or δ_0 at the time T_0; 7 the correction for $\Delta\mu_0$ to reduce these to 1875; 9 the coördi-

1 B. D. 26°.2324 (2 CHASE).

α_{1875}	12^h	12^m	$22^s.88$	μ,	$0^s.000$
δ_{1875}	26°	52′	58″.1	μ',	0″.00

No. of Cat. Sec. I.	**Authority.**	Date of Obs. t	Epoch of Cat. T	No. of Obs. n	**Right Asc.** at Epoch of Cat. / **Declination** at Epoch of Cat.	Corr. for Errone's Proper Motion.	Reduction to 1875.
					h m s	s	m s
3	Lalande 23057	1794.31	1800	1	12 8 34.89	0.000	+3 48.021
5	Bessel (W_1.) 229	1829.33	1825	1	9 50.73	.000	+2 31.936
26	Paris$_3$ 15073	1874.7	1875	5	12 22.89	.000	—
29	A. G. C. 6058	1877.2	1875	6	12 22.88	.000	—
25	Romberg 2710	1880.3	1875	2	12 22.85	.000	—
					h m s	s	
	Results	**1873.63**	**1875**	**15**	**12 12 22.904**	**—0.004**	—
					° ′ ″	″	′ ″
3	Lalande 23057	1794.31	1800	1	26 77 55.4	0.00	—25 2.72
5	Bessel (W_1.) 229	1829.33	1825	1	69 41.5	.00	—16 41.64
26	Paris$_3$ 15073	1874.7	1875	5	52 58.6	.00	—
29	A. G. C. 6058	1877.2	1875	6	52 58.1	.00	—
25	Romberg 2710	1880.3	1875	2	52 58.6	.00	—
	Results	**1873.63**	**1875**	**15**	**26° 52′ 58″.12**	**+0″.12**	—

nates for 1875; 10 the probable error at the time T_0, and 11 that at 1875; 12 the weight of α_0 or δ_0 at the time T_0, that is $[p]$; 13 the final proper motion; 14 the probable error of the proper motion; and 15 its weight, $[CD]$, at T_0.

$J = +\ 3^s.03565$ $K = -\ 0.01215$ $P = +\ 0.014$

$L = -\ 20''.0250$ $M = +\ 0.0325$ $N = +\ 0.16$

Right Ascen. 1875. α Declination 1875. δ	System-atic Corr. A	$\alpha + A$. Bα $\delta + A$. Bδ	Weight. p	$\Delta\mu_0(t-T_0)$. Fα $\Delta\mu_0'(t-T_0)$. Fδ	Corrected R. A. 1875. Bα′=Bα+Fα Corrected Decl. 1875. Bδ′=Bδ+Fδ	$\alpha_0 - B\alpha'$ Vα $\delta_0 - B\delta'$ Vδ
h m s	s	s		s	s	s
12 12 22.911	+0.254	23.165	0.1	—0.206	22.959	—0.055
12 22.666	+0.190	22.856	0.1	—0.115	22.741	+0.163
12 22.890	+0.043	22.933	2.0	+0.003	22.936	—0.032
12 22.880	.000	22.880	1.0	+0.009	22.889	+0.015
12 22.850	—0.003	22.847	1.0	+0.017	22.864	+0.040
h m s	s	s		s	s	
12 12 22.900	±0.0146	± 0.0146	**4.2**	**—0.0026**	± 0.0010	**885**
° ′ ″	″	″		″	″	″
26 52 52.68	—2.60	50.08	0.1	+6.82	56.90	+1.22
52 59.86	—3.60	56.26	0.1	+3.81	60.07	—1.95
52 58.60	—0.22	58.38	2.0	—0.09	58.29	—0.17
52 58.10	.00	5 . 0	1.0	—0.31	57.79	+0.33
52 58.60	+0.01	58.61	1.0	—0.57	58.04	+0.08
26° 52′ 58″.24	±0″.195	± 0″.196	**4.2**	**+0″.086**	± 0″.0135	**885**

2 B. D. 26°.2326—43 Comæ Berenices (3 CHASE).

α_{1875} 12^h 12^m $43^s.81$ μ, $0^s.000$
δ_{1875} $26°$ $42'$ $10''.5$ μ', $-0''.03$

No. of Cat. Sec. I.	**Authority.**	Date of Obs. **t**	Epoch of Cat. **T**	No. of Obs. **n**	**Right Asc.** at Epoch of Cat. / **Declination** at Epoch of Cat.	Corr. for Errone's Proper Motion.	Reduction to 1875.
					h m s	s	m s
4	d'Agelet 2893	1785.25	1800	1	12 8 56.2	0.000	+3 47.961
3	Lalande 23065	1794.31	1800	1	8 55.83	.000	+3 47.961
2	Piazzi 39	1805.97	1800	5	8 55.70	.000	+3 47.961
5	Bessel (W$_1$.) 238	1830.32	1825	2	10 11.79	.000	+2 31.897
8	Taylor 5644	[1835.3]	1835	3	10 42.60	.000	+2 1.492
21	Bruxelles 5031	1866.66	1865	3	12 13.38	.000	+ 30.355
33	Radcl. An. 632	1870.32	1870	4	12 28.54	.000	+ 15.176
26	Paris$_3$ 15077	1872.8	1875	2	12 43.77	.000	—
29	A. G. C. 6061	1878.0	1875	6	12 43.81	.000	—
25	Romberg 2711	1879.4	1875	2	12 43.64	.000	—
					h m s	s	
	Results	**1863.01**	**1875**	**29**	**12 12 43.790**	**—0.059**	—
					° ′ ″	″	′ ″
4	d'Agelet 2893	1785.25	1800	1	26 67 16.3	—0.44	—25 4.86
3	Lalande 23065	1794.31	1800	1	67 16.2	—0.17	—25 4.86
2	Piazzi 39	1805.51	1800	9	67 16.5	+0.16	—25 4.86
5	Bessel (W$_1$.) 238	1830.32	1825	2	58 53.0	+0.16	—16 43.06
8	Taylor 5644	[1834.8]	1835	4	55 32.80	.00	—13 22.40
10	Robinson 2639	1849.30	1840	2	53 53.20	+0.28	—11 42.07
33	Radcl. An. 743	1868.24	1868	1	44 29.91	+0.01	— 2 20.38
21	Bruxelles 5031	1868.33	1865	4	45 30.98	+0.10	— 3 20.55
33	Radcl. An. 632	1870.29	1870	3	43 51.82	+0.01	— 1 40.27
26	Paris$_3$ 15077	1872.8	1875	2	42 10.9	—0.07	—
29	A. G. C. 6061	1878.0	1875	6	42 10.5	+0.09	—
25	Romberg 2711	1879.4	1875	2	42 10.8	+0.13	—
	Results	**1863.17**	**1875**	**37**	**26° 42′ 10″.40**	**+0″.25**	—

$J = +\ 3^{s}.03491$ $K = -0.01200$ $P = +0.013$
$L = -20''.0533$ $M = +0.0332$ $N = +0.16$

Right Ascen. 1875. **α** Declination 1875. **δ**	System- atic Corr. **A**	$\alpha + A$. **Bα** $\delta + A$. **Bδ**	Weight. **p**	$\Delta\mu_0(t-T_0)$. **Fα** $\Delta\mu_0'(t-T_0)$. **Fδ**	Corrected R. A. 1875. **Bα′=Bα+Fα** Corrected Decl. 1875. **Bδ′=Bδ+Fδ**	$\alpha_0 - B\alpha'$ **Vα** $\delta_0 - B\delta'$ **Vδ**
h m s	s	s		s	s	s
12 12 44.161	+0.332	44.493	0.1	—0.381	44.112	—0.322
12 43.791	+0.253	44.044	0.1	—0.337	43.707	+0.083
12 43.661	+0.253	43.914	0.3	—0.279	43.635	+0.155
12 43.687	+0.156	43.843	0.2	—0.160	43.683	+0.107
12 44.092	—0.059	44.033	0.5	—0.136	43.897	—0.107
12 43.735	+0.043	43.778	1.0	+0.018	43.796	—0.006
12 43.716	—0.071	43.645	1.0	+0.036	43.681	+0.109
12 43.770	+0.043	43.813	1.0	+0.048	43.861	—0.071
12 43.810	.000	43.810	1.0	+0.073	43.883	—0.093
12 43.640	—0.003	43.637	1.0	+0.080	43.717	+0.073
h m s	s	s		s	s	
12 12 43.731	±0.0120	± 0.0136	**6.2**	**—0.0049**	± 0.0005	**3306**
° ′ ″	″	″		″	″	″
26 42 11.00	—1.41	9.59	0.1	+1.64	11.23	—0.83
42 11.17	—2.63	8.54	0.1	+1.45	9 99	+0.41
42 11.80	—2.63	9.17	0.3	+1.21	10.38	+0.02
42 10.10	—0.22	9.88	0.2	+0.69	10.57	—0.17
42 10.40	—0 82	9.58	0.5	+0.60	10.18	+0.22
42 11.41	—0.84	10.57	0.2	+0.29	10.86	—0.46
42 9.54	+0.03	9.57	0.5	—0.11	9.46	+0.94
42 10.53	—0.01	10.52	1.0	—0 11	10.41	—0.01
42 11.56	—0.68	10.88	1.0	—0.15	10.73	—0.33
42 10.83	—0.22	10.61	1.0	—0.20	10.41	—0.01
42 10.59	.00	10.59	1.0	—0.31	10.28	+0.12
42 10.93	.00	10.93	1.0	—0.34	10.59	—0.19
26° 42′ 10″.65	±0″.152	± 0″.173	**6.9**	**—0″.009**	± 0″.0069	**3402**

3 B. D. 26°.2329—51 Comæ Berenices (5 CHASE).

α_{1875} 12^h 14^m 1^s.05 μ, 0^s.000
δ_{1875} 26° 41′ 42″.6 μ', + 0″.03

No. of Cat. Sec. I.	**Authority.**	Date of Obs. **t**	Epoch of Cat. **T**	No. of Obs. **n**	**Right Asc.** at Epoch of Cat. **Declination** at Epoch of Cat.	Corr. for Errone's Proper Motion.	Reduction to 1875.
					h m s	s	m s
4	d'Agelet 2909	1785.25	1800	1	12 10 14.1	0.000	+3 47.677
3	Lalande 23118	1794.31	1800	1	10 14.30	.000	+3 47.677
2	Piazzi 52	1802.99	1800	16	10 14.24	.000	+3 47.677
5	Bessel (W_1.) 270	1831.31	1825	1	11 29.76	.000	+2 31.708
8	Taylor 5659	[1835.3]	1835	2	12 0.53	.000	+2 1.341
21	Bruxelles 5045	1866.66	1865	3	13 30.84	.000	+ 30.318
33	Radcl. An. 636	1870.35	1870	2	13 46.25	.000	+ 15.157
33	Radcl. An. 624	1873.24	1873	1	13 55.03	.000	+ 6.063
26	Paris$_3$ 15100	1875.6	1875	3	14 1.09	.000	—
29	A. G. C. 6070	1876.3	1875	6	14 1.05	.000	—
25	Romberg 2725	1879.9	1875	2	14 1.02	.000	—
					h m s	s	
	Results	**1864.89**	**1875**	**38**	**12 14 1.255**	**—0.142**	—
					° ′ ″	″	′ ″
4	d'Agelet 2909	1785.25	1800	1	26 66 44.2	+0.44	—24 59.94
3	Lalande 23118	1794.31	1800	1	66 47.2	+0.17	—24 59.94
2	Piazzi 52	1804.05	1800	10	66 44.6	—0.12	—24 59.94
5	Bessel (W_1.) 270	1831.31	1825	1	58 18.9	—0.19	—16 39.76
8	Taylor 5659	[1834.8]	1835	4	55 3.11	.00	—13 19.74
10	Robinson 2649	1849.30	1840	2	53 26.22	—0.28	—11 39.75
33	Radcl. An. 747	1868.24	1868	1	44 2.01	—0.01	— 2 19.92
21	Bruxelles 5045	1868.33	1865	4	45 3.01	—0.10	— 3 19.88
33	Radcl. An. 636	1870.37	1870	1	43 25.55	—0.01	— 1 39.94
33	Radcl. An. 624	1873.24	1873	1	42 22.72	—0.01	— 39.97
26	Paris$_3$ 15100	1875.6	1875	3	41 42.5	—0.02	—
29	A. G. C. 6070	1876.3	1875	6	41 42.6	—0.04	—
25	Romberg 2725	1879.9	1875	2	41 43.5	—0.15	—
	Results	**1864.06**	**1875**	**37**	**26° 41′ 42″.94**	**0″.00**	—

$J = + 3^{s}.03116$ $K = - 0.01188$ $P = + 0.013$

$L = - 19''.9867$ $M = + 0.0356$ $N = + 0.16$

Right Ascen. 1875. **α**	Systematic Corr. **A**	$\alpha + A$. **B**$_\alpha$	Weight. **p**	$\Delta\mu_0(t-T_0)$ **F**$_\alpha$	Corrected R. A. 1875. **B**$_\alpha'$ = **B**$_\alpha$ + **F**$_\alpha$	$\alpha_0 - B_\alpha'$ **V**$_\alpha$
h m s	s	s		s	s	s
12 14 1.777	+0.332	2.109	0.1	—1.115	0.994	+0.261
14 1.977	+0.253	2.230	0.1	—0.988	1.242	+0.013
14 1.917	+0.253	2.170	0.3	—0.867	1.303	—0.048
14 1.468	+0.122	1.590	0.1	—0.470	1.120	+0.135
14 1.871	—0.059	1.812	0.3	—0.414	1.398	—0.143
14 1.158	+0.043	1.201	1.0	+0.025	1.226	+0.029
14 1.407	—0.071	1.336	0.5	+0.076	1.412	—0.157
14 1.093	.000[1]	1.093	0.5	+0.117	1.210	+0.045
14 1.090	+0.043	1.133	1.0	+0.150	1.283	—0.028
14 1.050	.000	1.050	1.0	+0.160	1.210	+0.045
14 1.020	— .003	1.017	1.0	+0.210	1.227	+0.028
h m s	s	s		s	s	
12 14 1.113	±0.0123	±0.0134	**5.9**	**—0.0140**	±0.0005	**3180**
Declination 1875. **δ**		$\delta + A$. **B**$_\delta$		$\Delta\mu_0'(t-T_0)$ **F**$_\delta$	Corrected Decl. 1875. **B**$_\delta'$ = **B**$_\delta$ + **F**$_\delta$	$\delta_0 - B_\delta'$ **V**$_\delta$
° ′ ″	″	″		″	″	″
26 41 44.70	—1.41	43.29	0.1	0.00	43.29	—0.35
41 47.43	—2.63	44.80	0.1	.00	44.80	—1.86
41 44.54	—2.63	41.91	0.3	.00	41.91	+1.03
41 38.95	+3.15	42.10	0.1	.00	42.10	+0.84
41 43.37	—0.81	42.56	0.5	.00	42.56	+0.38
41 46.19	—0.82	45.37	0.2	.00	45.37	—2.43
41 42.08	+0.03	42.11	0.5	.00	42.11	+0.83
41 43.03	—0.01	43.02	1.0	.00	43.02	—0.08
41 45.60	—0.68	44.92	0.5	.00	44.92	—1.98
41 42.74	—0.11	42.63	0.5	.00	42.63	+0.31
41 42.48	—0.22	42.26	1.0	.00	42.26	+0.68
41 42.56	.00	42.56	1.0	.00	42.56	+0.38
41 43.35	.00	43.35	1.0	.00	43.35	—0.41
26° 41′ 42″.94	±0″.153	± 0″.171	**6.8**	**+0″.030**	± 0″.0069	**3390**

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[1] NOTE: See Sect. II, Systematic Corrections to Radcliffe Annuals.

4 B. D. 27°.2114 (6 CHASE).

α_{1875} 12^h 14^m $2^s.52$ μ, $0^s.000$
δ_{1875} $27°$ $19'$ $1''.5$ μ', $-0''.13$

No. of Cat. Sec. I.	**Authority.**	Date of Obs. t	Epoch of Cat. T	No. of Obs. n	**Right Asc.** at Epoch of Cat. / **Declination** at Epoch of Cat.	Corr. for Errone's Proper Motion.	Reduction to 1875.
					h m s	s	m s
3	Lalande 23120	1794.31	1800	1	12 10 15.05	0.000	+3 47.598
12	Paris$_1$ 15101	1841.2	1845	2	12 31.76	.000	+1 30.954
9	Rümker 3916	[1841.3]	1836	1	12 4.481	.000	+1 58.262
16	Poulkova 1852	1841.32	1855	4	13 2.08	.000	+1 0.624
31	Cambr. An.	1847.31	1847	1	12 37.82	.000	+1 24.887
13	Jacob [4153]	1850.27	1850	4	12 46.66	.000	+1 15.788
14	Wrottesley 447	1851.1	1850	5	12 46.86	.000	+1 15.788
32	Edinb. An.	1856.22	1856	2	13 5.12	.000	+ 57.592
32	" "	1858.21	1858	5	13 11.16	.000	+ 51.527
32	" "	1864.26	1864	2	13 29.42	.000	+ 33.337
32	" "	1865.16	1865	1	13 32.36	.000	+ 30.306
20	Yarnall 5240	1866.0	1860	3	13 17.06	.000	+ 45.463
32	Edinb. An.	1868.26	1868	3	13 41.37	.000	+ 21.213
33	Radcl. An. 637	1870.24	1870	1	13 47.34	.000	+ 15.151
26	Paris$_3$ 15101	1875.3	1875	1	14 2.49	.000	—
29	A. G. C. 6071	1877.3	1875	7	14 2.52	.000	—
25	Romberg 2726	1879.4	1875	2	14 2.45	.000	—
30	Ten-Year 1927	1880.02	1880	3	14 17.660	.000	— 15.148
					h m s	s	
	Results	**1860.30**	**1875**	**48**	**12 14 2.624**	**—0.104**	—
					° ′ ″	″	′ ″
3	Lalande 23120	1794.31	1800	1	27 44 16.8	—0.74	—25 11.93
9	Rümker 3916	[1841.3]	1836	1	32 10.01	+0.69	—13 5.98
16	Poulkova 1852	1841.32	1855	4	25 46.2	—1.78	— 6 43.00
12	Paris$_1$ 15101	1845.3	1845	1	29 7.5	+0.04	—10 4.56
31	Camb. An.	1847.35	1847	1	28 27.98	+0.05	— 9 24.24
13	Jacob [4153]	1850.27	1850	4	27 26.19	+0.04	— 8 23.78
20	Yarnall 5240	1854.4	1860	3	24 3.7	—0.73	— 5 2.24
32	Edinb. An.	1855.31	1855	1	25 45.5	+0.04	— 6 43.00
32	" "	1858.21	1858	7	24 44.3	+0.03	— 5 42.54
32	" "	1859.25	1859	2	24 23.8	+0.03	— 5 22.39
32	" "	1860.23	1860	6	24 4.7	+0.03	— 5 2.24
32	" "	1863.19	1863	3	23 2.6	+0.02	— 4 1.78
32	" "	1864.26	1864	7	22 43.8	+0.03	— 3 41.64
32	" "	1865.26	1865	3	22 22.9	+0.03	— 3 21.48
33	Radcl. An. 413	1865.27	1865	2	22 23.63	+0.04	— 3 21.48
32	Edinb. An.	1866.27	1866	3	22 4.0	+0.04	— 3 1.33
32	" "	1867.23	1867	2	21 44.7	+0.03	— 2 41.18
32	" "	1868.27	1868	5	21 24.0	+0.04	— 2 21.04
33	Radcl. An. 748	1868.27	1868	3	21 21.96	+0.04	— 2 21.04
32	Edinb. An.	1869.31	1869	4	21 5.4	+0.04	— 2 0.89
33	Radcl. An. 637	1870.24	1870	1	20 42.88	+0.03	— 1 40.74
33	" " 594	1871.28	1871	4	20 22.74	+0.04	— 1 20.59
33	" " 625	1873.36	1873	2	19 40.56	+0.05	— 40.29
26	Paris$_3$ 15101	1875.3	1875	1	19 2.1	+0.04	—
29	A. G. C. 6071	1877.3	1875	7	19 1.5	+0.30	—
25	Romberg 2726	1879.4	1875	2	19 2.7	+0.57	—
30	Ten-Year 1927	1880.02	1880	3	17 22.98	.00	+ 1 40.73
	Results	**1863.38**	**1875**	**83**	**27° 19′ 1″.98**	**+0″.28**	—

$J = +3^s.02997$ $K = -0.01225$ $P = +0.014$
$L = -20''.1466$ $M = +0.0357$ $N = +0.16$

Right Ascen. 1875. **a** Declination 1875. **δ**	Systematic Corr. **A**	$a + A$. **B**$_a$ $\delta + A$. **B**$_\delta$	Weight. **p**	$\Delta\mu_0(t-T_0)$. **F**$_a$ $\Delta\mu_0'(t-T_0)$. **F**$_\delta$	Corrected R. A. 1875. **B**$_a'$=**B**$_a$+**F**$_a$ Corrected Decl. 1875. **B**$_\delta'$=**B**$_\delta$+**F**$_\delta$	$a_0 - B_a'$ **v**$_a$ $\delta_0 - B_\delta'$ **v**$_\delta$
h m s	s	s		s	s	s
12 14 2.648	+0.255	2.903	0.1	—0.469	2.434	+0.190
14 2.714	+0.047	2.761	0.7	—0.136	2.625	—0.001
14 2.743	+0.039	2.782	0.1	—0.135	2.647	—0.023
14 2.704	+0.058	2.762	2.0	—0.135	2.627	—0.003
14 2.707	.000[1]	2.707	0.3	—0.092	2.615	+0.009
14 2.448	+0.310	2.758	0.5	—0.071	2.687	—0.063
14 2.648	+0.163	2.811	0.5	—0.065	2.746	—0.122
14 2.712	—0.087	2.625	0.1	—0.029	2.596	+0.028
14 2.687	—0.087	2.600	0.6	—0.015	2.585	+0.039
14 2.757	—0.070	2.687	0.1	+0.028	2.715	—0.091
14 2.666	—0.042	2.624	0.1	+0.035	2.659	—0.035
14 2.523	+0.033	2.556	0.6	+0.040	2.596	+0.028
14 2.583	—0.042	2.541	0.3	+0.057	2.598	+0.026
14 2.491	—0.071	2.420	0.5	+0.071	2.491	+0.133
14 2.490	+0.043	2.533	0.5	+0.106	2.639	—0.015
14 2.520	.000	2.520	1.0	+0.121	2.641	—0.017
14 2.450	—0.003	2.447	1.0	+0.136	2.583	+0.041
14 2.512	+0.010	2.522	1.0	+0.140	2.662	—0.038
h m s	s	s		s	s	
12 14 2.520	±0.0094	±0.0125	**10.0**	**—0.0071**	±0.0006	**2842**
° ′ ″	″	″		″	″	″
27 19 4.13	—2.58	1.55	0.1	+1.66	3.21	—1.23
19 4.72	—0.32	4.40	0.1	+0.53	4.93	—2.95
19 1.42	—0.02	1.40	2.0	+0.53	1.93	+0.05
19 2.98	—0.45	2.53	0.3	+0.43	2.96	—0.98
19 3.79	—1.62	2.17	0.3	+0.38	2.55	—0.57
19 2.45	—0.13	2.32	0.5	+0.31	2.63	—0.65
19 0.73	—0.10	0.63	0.6	+0.22	0.85	+1.13
19 2.54	—0.70	1.84	0.1	+0.19	2.03	—0.05
19 1.79	—0.66	1.13	0.6	+0.12	1.25	+0.73
19 1.44	—0.64	0.80	0.1	+0.10	0.90	+1.08
19 2.49	—0.62	1.87	0.6	+0.08	1.95	+0.03
19 0.84	+0.26	1.10	0.3	.00	1.10	+0.88
19 2.19	+0.28	2.47	0.6	—0.02	2.45	—0.47
19 1.45	—0.22	1.23	0.3	—0.05	1.18	+0.80
19 2.18	—0.40	1.78	0.5	—0.05	1.73	+0.25
19 2.71	—0.07	2.64	0.3	—0.07	2.57	—0.59
19 3.55	—0.07	3.48	0.1	—0.09	3.39	—1.41
19 3.00	—0.06	2.94	0.6	—0.12	2.82	—0.84
19 0.96	+0.02	0.98	1.0	—0.12	0.86	+1.12
19 4.55	—0.05	4.50	0.3	—0.14	4.36	—2.38
19 2.17	—0.68	1.49	0.5	—0.16	1.33	+0.65
19 2.19	—0.30	1.89	1.0	—0.19	1.70	+0.28
19 0.32	—0.11	0.21	0.5	—0.24	— .03	+2.01
19 2.14	—0.22	1.92	0.5	—0.29	1.63	+0.35
19 1.80	.00	1.80	1.0	—0.33	1.47	+0.51
19 3.27	+0.03	3.30	1.0	—0.38	2.92	—0.94
19 3.71	+0.08	3.79	1.0	—0.40	3.39	—1.41
27° 19′ 2″.26	±0″.104	±0″.136	**14.8**	**—0″.106**	±0″.0075	**2829**

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[1] Note: See Sect. II, Systematic Corrections to Cambridge Annuals.

5 B. D. 26°.2332 (9 CHASE).

α_{1875}	12^h	14^m	$47^s.43$	μ,	$0^s.000$
δ_{1875}	$26°$	$24'$	$53''.1$	μ',	$0''.00$

No. of Cat. Sec. I.	**Authority.**	Date of Obs. t	Epoch of Cat. T	No. of Obs. n	**Right Asc.** at Epoch of Cat. / **Declination** at Epoch of Cat.	Corr. for Errone's Proper Motion.	Reduction to 1875.
					h m s	s	m s
3	Lalande 23134	1794.32	1800	1	12 10 59.80	0.000	+3 47.539
5	Bessel (W_1.) 289	1831.31	1825	1	12 15.91	.000	+2 31.618
12	$Paris_1$ 15113	1848.0	1845	1	13 16.36	.000	+1 30.935
17	Argelander 2332	1858.29	1855	1	13 46.54	.000	+1 0.612
29	A. G. C. 6078	1875.1	1875	5	14 47.43	.000	—
					h m s	s	
	Results	**1861.01**	**1875**	**9**	**12 14 47.409**	**—0.022**	—
					° ′ ″	″	′ ″
3	Lalande 23134	1794.32	1800	1	26 50 4.9[1]	0.00	—25 1.91
5	Bessel (W_1.) 289	1831.31	1825	1	41 33.1	.00	—16 41.07
17	Argelander 2332	1858.29	1855	1	31 35.1	.00	— 6 40.32
26	$Paris_3$ 15113	1873.3	1875	1	24 53.9	.00	—
29	A. G. C. 6078	1875.1	1875	5	24 53.1	.00	—
	Results	**1866.30**	**1875**	**9**	**26° 21′ 53″.82**	**—0″.68**	—

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[1] NOTE: According to $Paris_3$, p. [99] this should be corrected — 10″; I have not

$J = +\ 3^s.02942$ $K = -0.01164$ $P = +\ 0.013$
$L = -20''.0125$ $M = +0.0371$ $N = +\ 0.16$

Right Ascen. 1875. α Declination 1875. δ	Systematic Corr. A	$\alpha + A$. B_α $\delta + A$. B_δ	Weight. p	$\Delta\mu_0(t - T_0)$ F_α $\Delta\mu_0'(t - T_0)$ F_δ	Corrected R. A. 1875. $B_\alpha' = B_\alpha + F_\alpha$ Corrected Decl. 1875. $B_\delta' = B_\delta + F_\delta$	$\alpha_0 - B_\alpha'$ v_α $\delta_0 - B_\delta'$ v_δ
h m s	s	s		s	s	s
12 14 47.339	+0.253	47.592	0.1	−0.107	47.485	−0.076
14 47.528	+0.122	47.650	0.1	−0.048	47.602	−0.193
14 47.295	+0.047	47.342	0.3	−0.021	41.321	+0.088
14 47.152	+0.037	47.189	0.2	−0.004	47.185	+0.224
14 47.430	.000	47.430	1.0	+0.023	47.453	−0.044
h m s	s	s		s	s	
12 14 47.387	±0.0229	± 0.0273	**1.7**	**−0.0016**	± 0.0011	**784**
° ′ ″	″	″		″	″	″
26 24 62 99	−2.63	60.36	0.1	−5.61	54.75	−0.93
24 52.03	+3.15	55.18	0.1	−2.73	52.45	+1.37
24 54.78	−0.94	53.84	0.2	−0.62	53 22	+0.60
24 53.90	−0.22	53.68	0.5	+0.55	54 23	−0.41
24 53.10	.00	53.10	1.0	+0.69	53.79	+0.03
° ′ ″	″	″		″	″	
26 24 53.14	±0 290	± 0.317	**1.9**	**−0.078**	± 0.0146	**755**

done so, however, for obvious reasons.

6 B. D. 25°.2493 (10 CHASE).

α_{1875}	12^h	14^m	$47^s.52$	μ, $0^s.000$
δ_{1875}	25°	43′	14″.9	μ', 0″.00

No. of Cat. Sec. I.	Authority.	Date of Obs. t	Epoch of Cat. T	No. of Obs. n	Right Asc. at Epoch of Cat. / Declination at Epoch of Cat.	Corr. for Errone's Proper Motion.	Reduction to 1875.
					h m s	s	m s
3	Lalande 23136	1794.32	1800	1	12 11 1.00	0.000	+3 47.624
31	Cambr. An.	1845.24	1845	3	13 16.98	.000	+1 30.972
24	Dreyer 1417	1872.65	1875	3	14 47.45	.000	—
26	Paris$_3$ 15114	1873.1	1875	4	14 47.61	.000	—
29	A. G. C. 6079	1880.4	1875	5	14 47.52	.000	—
					h m s	s	
	Results	**1865.34**	**1875**	**16**	**12 14 47.744**	**—0.160**	—
3	Lalande 23136	1794.32	1800	1	25° 68′ 8″.0	0″.00	—25′ 1″.91
31	Cambr. An.	1843.36	1843	1	53 52.29	.00	—10 40.59
31	" "	1845.34	1845	1	53 10.91	.00	—10 0.54
26	Paris$_3$ 15114	1873.1	1875	5	43 14.9	.00	—
24	Dreyer 1417	1875.82	1875	2	43 13.7	.00	—
29	A. G. C. 6079	1880.4	1875	5	43 14.9	.00	—
	Results	**1869.33**	**1875**	**15**	**25° 43′ 13″.66**	**+0″.82**	—

$J = + \ 3^s.03071$ $K = - 0.01121$ $P = + 0.013$
$L = - 20''.0125$ $M = + 0.0371$ $N = + 0.16$

Right Ascen. 1875. **a**	System-atic Corr.	$a + A$. $\mathbf{B}_\alpha$	Weight.	$\Delta\mu_0(t - T_0)$. $\mathbf{F}_\alpha$	Corrected R. A. 1875. $\mathbf{B}_\alpha' = \mathbf{B}_\alpha + \mathbf{F}$	$a_0 - B_\alpha'$ $\mathbf{v}_\alpha$
Declination 1875. **δ**	**A**	$\delta + A$. $\mathbf{B}_\delta$	**p**	$\Delta\mu_0'(t - T_0)$ $\mathbf{F}_\delta$	Corrected Decl. 1875. $\mathbf{B}_\delta' = \mathbf{B}_\delta + \mathbf{F}_\delta$	$\delta_0 - B_\delta'$ $\mathbf{v}_\delta$
h m s	s	s		s	s	s
12 14 48.624	+0.253	48.877	0.1	− 1.179	47.698	+0.046
14 47.952	+0.147	48.099	1.0	− 0.334	47.765	−0.021
14 47.450	+0.039	47.489	0.6	+ 0.121	47.610	+0.134
14 47.610	+0.042	47.652	1.0	+ 0.129	47.781	−0.037
14 47.520	.000	47.520	1.0	+ 0.250	47.770	−0.026
h m s	s	s		s	s	
12 14 47.584	±0.0154	± 0.0174	**3.7**	− **0.0166**	± 0.0008	**1227**
° ′ ″	″	″		″	″	″
25 43 6.09	−2.69	3.40	0.1	+10.80	14.20	−0.54
43 11.70	−1.28	10.42	0.3	+ 3.74	14.16	−0.50
43 10.37	−1.59	8.78	0.3	+ 3.45	12.23	+1.43
43 14.90	−0.22	14.68	2.0	− 0.54	14.14	−0.48
43 13.70	+0.28	13.98	0.6	− 0.93	13.05	+0.61
43 14.90	.00	14.90	1.0	− 1.59	13.31	+0.35
25° 43′ 14″.48	±0″.193	± 0″.205	**4.3**	+ **0″.144**	± 0″.0120	**1114**

7 B. D. 25°.2495 (11 CHASE).

α_{1875} 12^h 15^m $9^s.06$ μ, $0^s.000$
δ_{1875} $25°$ $41'$ $27''.9$ μ', $0''.00$

No. of Cat. Sec. I.	**Authority.**	Date of Obs. **t**	Epoch of Cat. **T**	No. of Obs. **n**	**Right Asc.** at Epoch of Cat. / **Declination** at Epoch of Cat.	Corr. for Errone's Proper Motion.	Reduction to 1875.
					h m s	s	m s
3	Lalande 23132	1794.32	1800	1	12 11 21.33	0.000	+3 47.551
31	Cambr. An.	1842.34	1842	3	13 29.36	.000	+1 40.043
31	" "	1844.18	1844	1	13 35.03	.000	+1 33.976
31	" "	1845.25	1845	1	13 38.01	.000	+1 30.943
26	Paris$_3$ 15120	1874.6	1875	3	15 9 10	.000	—
29	A. G. C. 6081	1877.7	1875	3	15 9.06	.000	—
					h m s	s	
	Results	**1859.70**	**1875**	**12**	**12 15 9.167**	**—0.049**	—
					° ′ ″	″	′ ″
3	Lalande 23132	1794.32	1800	1	25 66 33.0	0.00	—25 1.78
31	Cambr. An.	1842.37	1842	3	52 28.46	.00	—11 0.55
31	" "	1843.36	1843	1	52 10.52	.00	—10 40.53
31	" "	1844.38	1844	2	51 50.21	.00	—10 20.50
31	" "	1845.34	1845	2	51 30.59	.00	—10 0 48
26	Paris$_3$ 15120	1874.6	1875	3	41 28.4	.00	—
29	A. G. C. 6081	1877.7	1875	3	41 27.9	.00	—
	Results	**1856.23**	**1875**	**15**	**25° 41′ 27″.93**	**+0″.08**	

$J = +3^s.02976$ $K = -0.01116$ $P = +0.013$
$L = -20''.0104$ $M = +0.0378$ $N = +0.16$

Right Ascen. 1875. **α** Declination 1875. **δ**	System-atic Corr. **A**	$a + A$. **Bα** $\delta + A$. **Bδ**	Weight. **p**	$\Delta\mu_0(t - T_0)$. **Fα** $\Delta\mu_0'(t - T_0)$. **Fδ**	Corrected R. A. 1875. **Bα′=Bα+Fα** Corrected Decl. 1875. **Bδ′= Bδ+Fδ**	$a_0 - B_\alpha'$ **vα** $\delta_0 - B_\delta'$ **vδ**
h m s	s	s		s	s	s
12 15 8.881	+0.253	9.134	0.1	—0.209	8.925	+0.242
15 9.403	—0.075	9.328	1.0	—0.056	9.272	—0.105
15 9.006	+0.147	9.153	0.3	—0.050	9.103	+0.064
15 8.953	+0.147	9.100	0.3	—0.046	9.054	+0.113
15 9.100	+0.042	9.142	1.0	+0.048	9.190	—0.023
15 9.060	.000	9.060	1.0	+0.058	9.118	+0.049
h m s	s	s		s	s	
12 15 9.118	±0.0154	±0.0196	**3.7**	**—0.0032**	±0.0008	**1410**
° ′ ″	″	″		″	″	″
25 41 31.22	—2.69	28.53	0.1	+0.25	28.78	—0.85
41 27.91	—1.29	26.62	1.0	+0.06	26.68	+1.25
41 29.99	—1.28	28.71	0.3	+0.05	28.76	—0.83
41 29.71	—1.26	28.45	0.7	+0.05	28.50	—0.57
41 30.11	—1.59	28.52	0.7	+0.04	28.56	—0.63
41 28.40	—0.22	28.18	1.0	—0.07	28.11	—0.18
41 27.90	.00	27.90	1.0	—0.09	27.81	+0.12
25° 41′ 28″.01	±0″.183	± 0″.262	**4.8**	**+0″.004**	± 0″.0100	**1605**

8 B. D. 26°.2337 — 12e Comæ Berenices (d CHASE).—R. A.

α_{1875} 12h 16m 13s.22 μ, —0s.0017
δ_{1875} 26° 32′ 22″.7 μ', +0″.006

No. of Cat. Sec. I.	Authority.	Date of Obs. t	Epoch of Cat. T	No. of Obs. n	Right Asc. at Epoch of Cat.	Corr. for Errone's Proper Motion.	Reduction to 1875.
					h m s	s	m s
1	Bradley 1658	1755.4	1755	4	12 0 9.56	0.000	+6 3.656
4	d'Agelet 2925	1784.38	1800	2	12 26.20	—0.027	+3 47.081
3	Lalande 23169	1794.31	1800	1	12 25.85	—0.010	+3 47.081
2	Piazzi 59	1800.68	1800	13	12 26.04	+0.001	+3 47.081
6	Σ. Cat. Spec. 412	1823.74	1824	5	13 38.83	—0.001	+2 34.342
7	Pond 501	1831.07	1830	10	13 57.06	+0.001	+2 16.168
8	Taylor 5673	[1832.7]	1835	15	14 12.19	—0.004	+2 1.026
12	Paris$_1$ 15141	1840.0	1845	7	14 42.43	—0.008	+1 30.752
11	Gilliss 605	1840.29	1840	1	14 27.039	.000	+1 45.888
9	Rümker 3932	[1841]	1836	3	14 15.105	+0.008	+1 57.998
32	Edinb. An.	1842.28	1842	3	14 33.37	.000	+1 39.833
16	Poulkova 1859	1842.32	1855	4	15 12 64	.000	+1 0.490
10	Robinson 2658	1846.64	1840	4	14 27.25	+0.011	+1 45.888
18	Seven-Year 976	1859.3	1860	6	15 27.86	—0.003	+ 45.363
20	Yarnall 5253	1863 3	1860	3	15 27.83	+0.006	+ 45.363
19	Paris$_2$ 15141	1863.7	1860	21	15 27.79	+0.006	+ 45.363
22	Safford 194	1865.41	1865	7	15 43.016	+0.001	+ 30.239
21	Bruxelles 5062	1871.37	1865	3	15 42.91	+0.011	+ 30.239
27	Rogers 533	1873.7	1875	16	16 13.233	.000	—
26	Paris$_3$ 15141	1874.6	1875	4	16 13.21	—0.001	—
25	Romberg 2741	1874.9	1875	8	16 13.20	.000	—
23	Nine-Year 1140	1875.3	1872	3	16 4.145	—0.001	+ 9.070
34	Madras An. 466	1878.34	1878	2	16 22.33	+0.001	— 9.070
30	Ten-Year 1933	1878.81	1880	4	16 28.309	.000	— 15.115
34	Madras An. 539	1879.28	1879	3	16 25 07	.000	— 12.092
29	A. G. C. 6089	1880.0	1875	3	16 13.22	+0.008	—
35	Green. An. 777	1888.32	1888	3	16 52.493	.000	— 39.294
35	" " 1552	1894.45	1894	3	17 10.560	.000	— 57.422
					h m s	s	
	Results	**1859.97**	**1875**	**161**	**12 16 13.210**	**—0.008**	—

$J = + \ 3^s.02333$ $\quad K = -0.01158$ $\quad P = +0.013$

$L = - 19''.9980$ $\quad M = +0.0398$ $\quad N = +0.16$

Right Asc. 1875. **a**	System-atic Corr. **A**	$a + A$. **Ba**	Weight. **p**	$\Delta\mu_0(t - T_0)$ **Fa**	Corrected R. A. 1875. **Ba′=Ba+Fa**	$a_0 - B_a'$ **Va**
h m s	s	s		s	s	s
12 16 13.216	0.000	13.216	0.5	—0.052	13.164	+0.046
16 13.254	+0.332	13.586	0.2	—0.038	13.548	—0 338
16 12.921	+0.253	13.174	0.1	—0.033	13.141	+0.069
16 13.122	+0.253	13.375	0.3	—0 030	13.345	—0.135
16 13.171	+0.044	13.215	2.0	—0.018	13.197	+0 013
16 13.229	—0.017	13.212	1.0	—0.014	13.198	+0.012
16 13.212	—0.058	13 154	0.5	—0 014	13.140	+0.070
16 13 174	+0.047	13.221	2.0	—0.010	13.211	—0.001
16 12.927	—0.049	12.878	0.1	—0.010	12.868	+0.342
16 13.111	+0.037	13.148	0.3	—0.009	13.139	+0.071
16 13.203	—0.012	13.191	0.3	—0.009	13.182	+0.028
16 13.130	+0.059	13.189	2.0	—0.009	13.180	+0.030
16 13 149	+0.068	13.217	0.3	—0.007	13.210	.000
16 13.220	—0.013	13 207	2.0	.000	13.207	+0.003
16 13.199	+0.032	13.231	0.6	+0.002	13.233	—0.023
16 13.159	+0.051	13.210	3.0	+0.002	13.212	—0.002
16 13.256	+0.006	13.262	2.0	+0.003	13.265	—0.055
16 13.160	+0.044	13 204	1.0	+0.006	13.210	.000
16 13.233	+0.004	13.237	3.0	+0.007	13.244	—0.034
16 13.209	+0.042	13.251	1.0	+0.007	13.258	—0.048
16 13.200	—0.003	13.197	4.0	+0.007	13.204	+0.006
16 13.214	+0.006	13 220	1.0	+0.008	13.228	—0.018
16 13.261	+0.018	13.279	0.7	+0.009	13.288	—0.078
16 13.194	+0.010	13.204	1.0	+0.009	13.213	—0.003
16 12.978	+0.018	12.996	1.0	+0.010	13.006	+0.204
16 13.228	.000	13.228	1.0	+0.010	13.238	—0.028
16 13.199	+0 010	13 209	1.0	+0.014	13.223	—0.013
16 13.138	+0.010	13.148	1.0	+0.017	13.165	+0.045
h m s	s	s		s	s	
12 16 13.202	±0 0052	± 0.0062	**32.9**	**—0.0022**	± 0.0002	**19151**

8 B. D. 26°.2337 — 12e Comæ Berenices (d CHASE).—Decl.

α_{1875}	12^h	16^m	13^s.22	μ, —0^s.0017
δ_{1875}	26°	32′	22″.7	μ, +0″.006

No. of Cat Sec. I.	**Authority.**	Date of Obs. **t**	Epoch of Cat. **T**	No. of Obs. **n**	**Declination** at Epoch of Cat.	Corr. for Errone's Proper Motion.	Reduction to 1875.
					° ′ ″	″	′ ″
1	Bradley 1658	1754.3	1755	3	26 72 26.8	0.00	—40 2.35
4	d'Agelet 2925	1784.38	1800	2	57 26.2	+0.09	—25 0.90
3	Lalande 23169	1794.31	1800	1	57 27.1	+0.03	—25 0.90
2	Piazzi 59	1800.68	1800	16	57 25.5	.00	—25 0.90
6	Σ. Cat. Spec. 412	1823.74	1824	5	49 24.6	.00	—17 0.39
7	Pond 501	1831.53	1830	12	47 25.9	—0.01	—15 0.30
8	Taylor 5673	[1831.9]	1835	5	45 44.34	+0.02	—13 20.23
12	Paris$_1$ 15141	1838.8	1845	2	42 25 9	+0.04	—10 0.12
9	Rümker 3932	[1841]	1836	3	45 24.34	—0.03	—13 0.22
32	Edinb. An.	1842.28	1842	3	43 25.1	.00	—11 0.15
16	Poulkova 1859	1842.32	1855	4	39 4.6	.00	— 6 40 04
10	Robinson 2658	1853.2	1840	3	44 4.37	—0.08	—11 40.17
18	Seven-Year 976	1859.3	1860	6	37 24.40	.00	— 5 0.02
21	Bruxelles 5062	1868.31	1865	1	35 44.46	—0.02	— 3 20.00
20	Yarnall 5253	1872.2	1860	4	37 25 9	—0.07	— 5 0.02
27	Rogers 533	1873.7	1875	16	32 24.01	.00	—
23	Nine Year 1140	1874 4	1872	11	33 24.18	—0.01	— 1 0.00
26	Paris$_3$ 15 41	1874.6	1875	4	32 23.8	.00	—
25	Romberg 2741	1874.9	1875	8	32 24.3	.00	—
28	Respighi 684	1875.76	1875	26	32 23.84	.00	—
34	Madras An. 466	1878.34	1878	2	31 23.5	.00	+ 59.99
34	" " 539	1879.28	1879	3	31 4.4	.00	+ 1 19.99
30	Ten-Year 1933	1879 63	1880	17	30 44.14	.00	+ 1 39.98
29	A. G. C. 6 89	1880.0	1875	3	32 22.7	—0.03	—
35	Green. An. 777	1888 32	1888	6	28 3.56	.00	+ 4 19.94
35	" " 1552	1894.39	1894	5	26 3.60	.00	+ 6 19.89
	Resu'ts	**1865.03**	**1875**	**171**	**26°32′23″.97**	**+0″.01**	—

$J = + 3^{s}.02333$ $K = - 0.01158$ $P = + 0.013$
$L = - 19''.9980$ $M = + 0.0398$ $N = + 0.16$

Declination 1875. **δ**	Systematic Corr. **A**	$\delta + A$. **Bδ**	Weight. **p**	$\Delta\mu_0'(t - T_0)$. **Fδ**	Corrected Decl. 1875. **Bδ′ = Bδ + Fδ**	$\delta_0 - B\delta'$ **vδ**
26° 32′ 24″.45	0″.00	24″.45	0.4	+0″.11	24″.56	—0″.59
32 25.39	—1.41	23.98	0.2	+0.08	24.06	—0.09
32 26.23	—2.63	23.60	0.1	+0.07	23.67	+0.30
32 24.60	—2.63	21.97	0.3	+0.06	22 03	+1.94
32 24.21	—1.04	23.17	2.0	+0.04	23.21	+0.76
32 25.59	—1.90	23.69	1.0	+0.03	23.72	+0.25
32 24.13	—0.84	23.29	0.5	+0.03	23.32	+0.65
32 25.82	—0.45	25.37	0.7	+0.03	25.40	—1.43
32 24.09	—0.30	23.79	0.3	+0.02	23 81	+0.16
32 24.95	—1.12	23.83	0.3	+0.02	23.85	+0.12
32 24.56	—0.02	24.54	2.0	+0.02	24.56	—0.59
32 24.12	—0.82	23.30	0.3	+0.01	23.31	+0.66
32 24.38	—0.09	24.29	2.0	+0 01	24.30	—0.33
32 24.44	—0.03	24.41	0.3	.00	24.41	—0.44
32 25.81	—0.11	25.70	0.6	—0.01	25 69	—1.72
32 24.01	+0.26	24.27	3.0	—0.01	24.26	—0.29
32 24.17	—0.46	23.71	3.0	—0.01	23.70	+0.27
32 23.80	—0.22	23.58	1.0	—0.01	23.57	+0.40
32 24.30	.00	24.30	4.0	—0.01	24.29	—0.32
32 23.84	+0.41	24.25	1.5	—0.01	24.24	—0.27
32 23.49	—0.29	23.20	0.7	—0.01	23.19	+0.78
32 24.39	—0.29	24.10	1.0	—0.01	24.09	—0.12
32 24.12	+0.08	24.20	3.0	—0.01	24.19	—0.22
32 22.67	.00	22 67	1.0	—0.01	22.66	+1.31
32 23.50	+0.09	23.59	2.0	—0.02	23.57	+0.40
32 23.49	+0.09	23.58	2.0	—0.03	23.55	+0.42
26° 32′ 23″.98	±0″.069	± 0″.074	**33.2**	**+0″.007**	± 0″.0028	**20154**

9 B. D. 26°.2338 (14 CHASE).

α_{1875} 12h 16m 14s.37 μ, 0s.000

δ_{1875} 26° 31′ 20″.5 μ', 0″.00

No. of Cat. Sec. I.	Authority.	Date of Obs. t	Epoch of Cat. T	No. of Obs. n	Right Asc. at Epoch of Cat. Declination at Epoch of Cat.	Corr. for Errone's Proper Motion.	Reduction to 1875.
					h m s	s	m s
17	Argelander 2338	1858.22	1855	1	12 15 13.77	0.000	+1 0.523
21	Bruxelles 5063	1871.37	1865	3	15 43.96	.000	+ 30.256
29	A. G. C. 6090	1877.3	1875	3	16 14.37	.000	—
25	Romberg 2742	1877.6	1875	4	16 14.27	.000	—
					h m s	s	
	Results	**1875.12**	**1875**	**11**	**12 16 14.293**	**0.000**	—
					° ′ ″	″	′ ″
10	Robinson 2659	1853.68	1840	2	26 42 59.48	0.00	—11 40.38
17	Argelander 2338	1858.22	1855	1	37 59.4	.00	— 6 40.16
21	Bruxelles 5063	1868.31	1865	1	34 40.58	.00	— 3 20.06
29	A. G. C. 6090	1877.3	1875	3	31 20.5	.00	—
25	Romberg 2742	1877.6	1875	4	31 20.4	.00	—
	Results	**1874.43**	**1875**	**11**	**26° 31′ 20″.21**	**+0″.05**	—

$J = +\ 3^{s}.02501$ $K = -\ 0.01157$ $P = +\ 0.013$
$L = -\ 20''.0039$ $M = +\ 0.0398$ $N = +\ 0.16$

Right Asc. 1875. α Declination 1875. δ	Systematic Corr. **A**	$\alpha + A$. **B**$_\alpha$ $\delta + A$. **B**$_\delta$	Weight. **p**	$\Delta\mu_0(t - T_0)$ **F**$_\alpha$ $\Delta\mu_0'(t - T_0)$ **F**$_\delta$	Corrected R. A., 1875. **B**$_\alpha' =$ **B**$_\alpha +$ **F**$_\alpha$ Corrected Decl. 1875. **B**$_\delta' =$ **B**$_\delta +$ **F**$_\delta$	$\alpha_0 - B_\alpha'$ **v**$_\alpha$ $\delta_0 - B_\delta'$ **v**$_\delta$
h m s	s	s		s	s	s
12 16 14.293	+0.037	14.330	0.2	+0.007	14.337	—0.044
16 14.216	+0.044	14.260	1.0	+0.002	14.262	+0.031
16 14.370	.000	14.370	1.0	—0.001	14.369	—0.076
16 14.270	—0.003	14.267	2.0	—0.001	14.266	+0.027
h m s	s	s		s	s	
12 16 14.293	±0.0146	± 0.0146	**4.2**	**+0.0004**	± 0.0032	**88**
° ′ ″	″	″		″	″	″
26 31 19.10	—0.82	18.28	0.2	+1.83	20.11	+0.10
31 19.24	—0.94	18.30	0.2	+1.43	19.73	+0.48
31 20.52	—0.03	20.49	0.3	+0.54	21.03	—0.82
31 20.50	.00	20.50	1.0	—0.25	20.25	—0.04
31 20.40	.00	20.40	2.0	—0.28	20.12	+0.09
26° 31′ 20″.26	±0″.208	± 0″.209	**3.7**	**+0″.088**	±0″.0300	**178**

10 B. D. 26°.2343 (18 CHASE).

α_{1875} 12^h 17^m $46^s.97$ μ, $0^s.000$
δ_{1875} $26°$ $32'$ $40''6$ μ', $0''.00$

No. of Cat. Sec. I.	Authority.	Date of Obs. t	Epoch of Cat. T	No. of Obs. n	Right Asc. at Epoch of Cat. Declination at Epoch of Cat.	Corr. for Errone's Proper Motion.	Reduction to 1875.
					h m s	s	m s
3	Lalande 23207	1794.31	1800	1	12 14 0.18	0.000	+3 46.864
2	Piazzi 68	1804.46	1800	8	13 59.90	.000	+3 46.864
5	Bessel (W_1.) 348	1831.31	1825	1	15 15.38	.000	+2 31.169
12	Paris$_1$ 15178	1838.9	1845	3	16 16.30	.000	+1 30.666
8	Taylor 5688	[1839.8]	1835	6	15 46.16	.000	+2 0.911
10	Robinson 2663	1848.35	1840	1	16 1.30	.000	+1 45.787
33	Radcl. An. 750	1868.36	1868	2	17 25.86	.000	+ 21.146
21	Bruxelles 5068	1869.87	1865	2	17 16.72	.000	+ 30.210
33	Radcl. An. 595	1871.36	1871	2	17 34.88	.000	+ 12.083
26	Paris$_3$ 15178	1872.7	1875	5	17 46.97	.000	—
20	Yarnall 5268	1876.0	1860	3	17 1.60	.000	+ 45.320
29	A. G. C. 6100	1878.3	1875	4	17 46.97	.000	—
25	Romberg 2751	1878.4	1875	4	17 46.85	.000	—
					h m s	s	
	Results	**1865.15**	**1875**	**42**	**12 17 46.965**	**—0.020**	—
					° ′ ″	″	′ ″
3	Lalande 23207	1794.31	1800	1	26 57 44.3	0.00	—25 0.68
2	Piazzi 68	1804.46	1800	9	57 42.2	.00	—25 0.68
5	Bessel (W_1.) 348	1831.31	1825	1	49 16.6	.00	—16 40.21
8	Taylor 5688	[1838.8]	1835	8	46 1.09	.00	—13 20.09
10	Robinson 2663	1853.04	1840	5	44 21.84	.00	—11 40.05
33	Radcl. An. 642	1864.31	1864	2	36 21.81	.00	— 3 39.96
33	" " 750	1868.30	1868	1	34 58.53	.00	— 2 19.97
21	Bruxelles 5068	1868.31	1865	1	36 1.48	.00	— 3 19.96
33	Radcl. An. 571	1869.30	1869	2	34 40.53	.00	— 1 59.97
33	" " 595	1871.36	1871	2	34 1.30	.00	— 1 19.98
26	Paris$_3$ 15178	1872.7	1875	5	32 41.5	.00	—
33	Radcl. An. 714	1874.23	1874	2	32 59.55	.00	— 19.99
20	Yarnall 5268	1876.4	1860	2	37 41.1	.00	— 4 59.96
29	A. G. C. 6100	1878.3	1875	4	32 40.6	.00	—
25	Romberg 2751	1878.4	1875	4	32 40.7	.00	—
	Results	**1867.72**	**1875**	**49**	**26° 32′ 40″.61**	**+0″.11**	—

$J = +3^s.02048$ $K = -0.01145$ $P = +0.013$
$L = -19''.9939$ $M = +0.0427$ $N = +0.16$

Right Ascen. 1875. **α**	Systematic Corr. **A**	$\alpha + A$. **Bα**	Weight. **p**	$\Delta\mu_0(t-T_0)$. **Fα**	Corrected R. A. 1875. **Bα′=Bα+Fα**	$\alpha_0 - B\alpha'$ **Vα**
h m s	s	s		s	s	s
12 17 47.044	+0.253	47.297	0.1	—0.142	47.155	—0.190
17 46.764	+0.253	47.017	0.3	—0.121	46.896	+0.069
17 46.549	+0.122	46.671	0.1	—0.068	46.603	+0.362
17 46.966	+0.047	47.013	1.0	—0.052	46.961	+0.004
17 47.071	—0.058	47.013	0.5	—0.051	46.962	+0.003
17 47.087	+0.068	47.155	0.1	—0.034	47.121	—0.156
17 47.006	+0.033	47.039	0.5	+0.006	47.045	—0.080
17 46.930	+0.044	46.974	0.7	+0.009	46.983	—0.018
17 46.963	—0.020	46.943	0.5	+0.012	46.955	+0.010
17 46.970	+0.042	47.012	2.0	+0.015	47.027	—0.062
17 46.920	+0.031	46.951	0.6	+0.022	46.973	—0.008
17 46.970	.000	46.970	1.0	+0.026	46.996	—0.031
17 46.850	—0.003	46.847	2.0	+0.026	46.873	+0.092
h m s	s	s		s	s	
12 17 46.945	±0.0097	± 0.0109	**9.4**	**—0.0020**	± 0.0005	**3509**

Declination 1875. **δ**	Systematic Corr. **A**	$\delta + A$. **Bδ**	Weight. **p**	$\Delta\mu_0'(t-T_0)$. **Fδ**	Corrected Decl. 1875. **Bδ′=Bδ+Fδ**	$\delta_0 - B\delta'$ **Vδ**
° ′ ″	″	″		″	″	″
26 32 43.62	—2.62	41.00	0.1	+1.10	42.10	—1.49
32 41.52	—2.62	38.90	0.3	+0.95	39.85	+0.76
32 36.39	+3.15	39.54	0.1	+0.55	40.09	+0.52
32 41.00	—0.83	40.17	0.5	+0.43	40.60	+0.01
32 41.79	—0.82	40.97	0.5	+0.22	41.19	—0.58
32 41.85	—0.82	41.03	0.5	+0.05	41.08	—0.47
32 38.56	+0.02	38.58	0.5	—0.01	38.57	+2.04
32 41.52	—0.03	41.49	0.3	—0.01	41.48	—0.87
32 40.56	—0.40	40.16	0.5	—0.02	40.14	+0.47
32 41.32	—0.31	41.01	0.5	—0.05	40.96	—0.35
32 41.50	—0.22	41.28	2.0	—0.07	41.21	—0.60
32 39.56	—0.03	39.53	0.5	—0.10	39.43	+1.18
32 41.14	—0.09	41.05	0.6	—0.13	40.92	—0.31
32 40.60	.00	40.60	1.0	—0.16	40.44	+0.17
32 40.70	.00	40.70	2.0	—0.16	40.54	+0.07
26° 32′ 40″.72	±0″.127	± 0″.138	**9.9**	**+0″.015**	± 0″.0075	**2868**

11 B. D. 26°.2344—13f Comæ Berenices (19 CHASE).

α_{1875}	12^h	18^m	$2^s.16$	μ, — $0^s.0020$
δ_{1875}	26°	47′	30″.3	μ',— 0″.021

No. of Cat. Sec. I.	**Authority.**	Date of Obs. **t**	Epoch of Cat. **T**	No. of Obs. **n**	**Right Asc.** at Epoch of Cat. / **Declination** at Epoch of Cat.	Corr. for Errone's Proper Motion	Reduction to 1875.
					h m s	s	m s
1	Bradley 1661	1755.8	1755	6	12 11 59.35	0.000	+6 2.918
4	d'Agelet 2931	1783.37	1800	2	14 15.15	—0.033	+3 46.620
3	Lalande 23211	1794.31	1800	1	14 15.25	—0.011	+3 46.620
2	Piazzi 70	1801.28	1800	7	14 15.18	+0.003	+3 46.620
5	Bessel (W_1.) 351	1830.32	1825	2	15 31.10	+0.011	+2 31.005
7	Pond 502	1831.67	1830	6	15 46.49	+0.003	+2 15.891
8	Taylor 5691	[1832.3]	1835	12	16 1.42	—0.005	+2 0.780
10	Robinson 2665	1836.05	1840	7	16 16.44	—0.008	+1 45.672
12	Paris$_1$ 15182	1838.0	1845	9	16 31.57	—0.014	+1 30.567
11	Gilliss 608	1840.79	1840	13	16 16.470	+0.002	+1 45.672
9	Rümker 3950	[1841]	1836	7	16 4.359	+0.010	+1 30.758
16	Poulkova 1862	1841.34	1855	4	17 1.82	.000	+1 0.367
32	Edinb. An.	1842.28	1842	3	16 22.55	+0.001	+1 39.630
18	Seven-Year 977	1854.3	1860	3	17 17.01	—0.017	+ 45.271
19	Paris$_2$ 15182	1859.8	1860	2	17 16.80	.000	+ 45.271
21	Bruxelles 5072	1861.96	1865	3	17 31.97	—0.006	+ 30.178
22	Safford 195	1865.41	1865	6	17 32.035	+0.001	+ 30.178
27	Rogers 534	1872.6	1875	12	18 2.181	+0.001	—
34	Madras An. 468	1878.39	1878	3	18 11.08	+0.001	— 9.051
25	Romberg 2754	1878.4	1875	4	18 2.16	.000	—
29	A. G. C. 6102	1878.6	1875	4	18 2.16	+0.007	—
34	Madras An. 541	1879.31	1879	2	18 14.24	+0.001	— 12.068
30	Ten-Year 1935	1883.24	1880	3	18 17.234	.000	— 15.084
					h m s	s	
	Results	**1855.01**	**1875**	**121**	**12 18 2.182**	**—0.010**	—
					° ′ ″	″	′ ″
1	Bradley 1661	1754.2	1755	3	26 87 35.1	0.00	—40 4.42
4	d'Agelet 2931	1783.37	1800	2	72 31.4	—0.35	—25 2.14
3	Lalande 23211	1794.31	1800	1	72 32.5	—0.12	—25 2.14
2	Piazzi 70	1801.28	1800	9	72 34.0	+0.03	—25 2.14
5	Bessel (W_1.) 351	1830.32	1825	2	64 10.3	+0.11	—16 41.18
7	Pond 502	1831.06	1830	14	62 33.3	+0.02	—15 1.02
8	Taylor 5691	[1831.5]	1835	6	60 51.91	—0.07	—13 20.86
12	Paris$_1$ 15182	1838.0	1845	4	57 30.6	—0.15	—10 0.59
9	Rümker 3950	[1841]	1836	8	60 32.28	+0.10	—13 0.84
16	Poulkova 1862	1841.34	1855	4	54 11.00	.00	— 6 40.35
32	Edinb. An.	1842.30	1842	3	58 32.4	+0.01	—11 0.67
15	Six-Year 802	1849.3	1850	2	55 51.48	.00	— 8 20.46
10	Robinson 2665	1849.67	1840	5	59 11.46	+0.20	—11 40.73
18	Seven-Year 977	1854.3	1860	6	52 30.93	+0.05	— 5 0.25
19	Paris$_2$ 15182	1860.8	1860	2	52 30.9	+0.02	— 5 0.25
21	Bruxelles 5072	1862.77	1865	2	50 51.47	—0.05	— 3 20.15
27	Rogers 534	1872.6	1875	12	47 30.91	—0.01	—
28	Respighi 686	1875.31	1875	20	47 30.23	.00	—
34	Madras An. 468	1878.39	1878	3	46 32.2	+0.01	+ 1 0.04
25	Romberg 2754	1878.4	1875	4	47 31.3	.00	—
29	A. G. C. 6102	1878.6	1875	4	47 30.3	+0.08	—
34	Madras An. 541	1879.31	1879	2	46 12.0	.00	+ 1 20.05
30	Ten-Year 1935	1883.24	1880	3	45 50.62	.00	+ 1 40.06
	Results	**1857.40**	**1875**	**121**	**26° 47′ 30″.73**	**+0″.30**	—

$J = +\ 3^{s}.01718$ $K = -0.01156$ $P = +0.014$
$L = -20''.0132$ $M = +0.0432$ $N = +0.16$

Right Asc. 1875. **α** Declination 1875. **δ**	Systematic Corr. **A**	α + A. **Bα** δ + A. **Bδ**	Weight. **p**	$\Delta\mu_0(t-T_0)$ **Fα** $\Delta\mu_0'(t-T_0)$ **Fδ**	Corrected R. A. 1875. **Bα′ = Bα + Fα** Corrected Decl. 1875. **Bδ′ = Bδ + Fδ**	$a_0 - B_a'$ **Vα** $\delta_0 - B_\delta'$ **Vδ**
h m s	s	s		s	s	s
12 18 2.268	0.000	2.268	0.6	—0.050	2.218	—0.036
18 1.737	+0.333	2.070	0.2	—0.036	2.034	+0.148
18 1.859	+0.254	2.113	0.1	—0.030	2.083	+0.099
18 1.803	+0.254	2.057	0.3	—0.027	2.030	+0.152
18 2.116	+0.156	2.272	0.2	—0.012	2.260	—0.078
18 2.384	—0.017	2.367	0.6	—0.012	2.355	—0.173
18 2.195	—0.057	2.138	0.5	—0.011	2.127	+0.055
18 2.104	+0.068	2.172	0.5	—0.009	2.163	+0.019
18 2.123	+0.047	2.170	2.0	—0.009	2.161	+0.021
18 2.144	—0.049	2.095	1.0	—0.007	2.088	+0.094
18 2.127	+0.039	2.166	0.5	—0.007	2.159	+0.023
18 2.187	+0.059	2.246	2.0	—0 007	2.239	—0.057
18 2.181	—0.012	2.169	0.3	—0.006	2.163	+0.019
18 2.264	—0.013	2.251	1.0	.000	2.251	—0.069
18 2.071	+0.051	2.122	0.7	+0.002	2.124	+0.058
18 2.142	+0.044	2.186	1.0	+0.003	2.189	—0.007
18 2.214	+0.006	2.220	2.0	+0.005	2.225	—0.043
18 2.182	+0.003	2.185	3.0	+0.009	2.194	—0.012
18 2.030	+0.018	2.048	1.0	+0.012	2.060	+0.122
18 2.160	—0.003	2.157	2.0	+0.012	2.169	+0.013
18 2.167	.000	2.167	1.0	+0.012	2.179	+0.003
18 2.173	+0.018	2.191	0.7	+0.012	2.203	—0.021
18 2 150	+0.010	2.160	1.0	+0.014	2.174	+0.008
h m s	s	s		s	s	
12 18 2.172	±0.0063	±0.0081	**22.2**	**—0.0025**	±0.0002	**14971**
° ′ ″	″	″		″	″	″
26 47 30.68	0.00	30.68	0.4	+1.75	32.43	—1.70
47 28.91	—1.38	27.53	0.2	+1.26	28.79	+1.94
47 30.24	—2.60	27.64	0.1	+1.07	28.71	+2.02
47 31.89	—2.60	29.29	0.3	+0.95	30.24	+0.49
47 29.23	—0.22	29.01	0.2	+0.46	29.47	+1.26
47 32.30	—1.90	30.40	1.0	+0 45	30.85	—0.12
47 30.98	—0.80	30.18	0.5	+0.44	30.62	+0.11
47 29.86	—0.45	29 41	1.0	+0.33	29.74	+0.99
47 31.54	—0.30	31.24	0.5	+0.28	31.52	—0.79
47 30.65	—0.02	30.63	2.0	+0.27	30.90	—0.17
47 31.74	—1.12	30.62	0.3	+0.26	30.88	—0.15
47 31.02	—0.20	30.82	0.7	+0.14	30.96	—0.23
47 30.93	—0.82	30.11	0.5	+0.13	30.24	+0.49
47 30.73	—0.09	30.64	2.0	+0.05	30.69	+0.04
47 30.67	—0.28	30.39	0.7	—0.06	30.33	+0.40
47 31.27	—0.02	31.25	0.7	—0.09	31.16	—0.43
47 30.90	+0.26	31.16	3.0	—0.26	30.90	—0.17
47 30.23	+0.40	30.63	1.5	—0.30	30.33	+0.40
47 32.25	—0.29	32.96	1.0	—0.36	31.60	—0.87
47 31.30	+0.01	31.31	2.0	—0.36	30.95	—0.22
47 30.38	.00	30.38	1 0	—0.36	30.02	+0.71
47 32.05	—0.29	31.76	0.7	—0.37	31.39	—0.66
47 30.68	+0.08	30.76	1.0	—0.44	30.32	+0.41
26° 47′ 31″.03	±0″.087	± 0″.107	**21.3**	**—0″.004**	± 0″.0035	**13043**

12 B. D. 26°.2345—68 Comæ Berenices (20 CHASE).

α_{1875} 12^h 18^m 10^s.24 μ, 0^s.000
δ_{1875} 26° 16′ 33″.3 μ', 0″.00

No. of Cat. Sec. I.	Authority.	Date of Obs. t	Epoch of Cat. T	No. of Obs. n	Right Asc. at Epoch of Cat. / Declination at Epoch of Cat.	Corr. for Errone's Proper Motion.	Reduction to 1875.
					h m s	s	m s
4	d'Agelet 2933	1785.25	1800	1	12 14 23.7	0.000	+3 46.820
3	Lalande 23214	1794.31	1800	2	14 23.04	.000	+3 46.820
6	Σ.Pos. Med. 1417	1828.5	1830	6	15 54.38	.000	+2 16.014
16	Poulkova 1863	1841.32	1855	4	17 9.93	.000	+1 0.422
31	Camb. An.	1842.32	1842	3	16 30.70	.000	+1 39.720
19	Paris$_2$ 15186	1863.3	1860	1	17 24.99	.000	+ 45.312
21	Bruxelles 5073	1871.70	1865	3	17 40.00	.000	+ 30.205
24	Dreyer 1423	1873.30	1875	7	18 10.24	.000	—
26	Paris$_3$ 15186	1874.3	1875	7	18 10.27	.000	—
25	Romberg 2755	1875.3	1875	5	18 10.23	.000	—
29	A. G. C. 6104	1876.4	1875	2	18 10.24	.000	—
					h m s	s	
	Results	**1858.93**	**1875**	**41**	**12 18 10.317**	**—0.051**	—
					° ′ ″	″	′ ″
4	d'Agelet 2933	1785.25	1800	1	26 41 34.9	0.00	—25 0.50
3	Lalande 23214	1794.31	1800	2	41 35.4	.00	—25 0.50
6	Σ.Pos. Med. 1417	1828.5	1830	6	31 32.8	.00	—15 0.03
16	Poulkova 1863	1841.32	1855	4	23 13.2	.00	— 6 39.91
31	Camb. An.	1842.33	1842	3	27 33.82	.00	—10 59.95
21	Bruxelles 5073	1870.78	1865	2	19 53.00	.00	— 3 19.94
26	Paris$_3$ 15186	1874.3	1875	7	16 33.3	.00	—
25	Romberg 2755	1875.3	1875	5	16 33.2	.00	—
24	Dreyer 1423	1876.12	1875	5	16 32.7	.00	—
29	A. G. C. 6104	1876.4	1875	2	16 33.3	.00	—
	Results	**1858.81**	**1875**	**37**	**26° 16′ 32″.89**	**+0″.26**	—

$J = + 3^{s}.01997$ $K = - 0.01125$ $P = + 0.013$

$L = - 19''.9913$ $M = + 0.0435$ $N = + 0.16$

Right Asc. 1875. α	Systematic Corr.	$\alpha + A.$ $\mathbf{B}_\alpha$	Weight.	$\Delta\mu_0(t - T_0)$ $\mathbf{F}_\alpha$	Corrected R. A. 1875. $\mathbf{B}_\alpha' = \mathbf{B}_\alpha + \mathbf{F}_\alpha$	$\alpha_0 - B_\alpha'$ $\mathbf{V}_\alpha$
Declination 1875. δ	$\mathbf{A}$	$\delta + A.$ $\mathbf{B}_\delta$	$\mathbf{p}$	$\Delta\mu_0'(t - T_0).$ $\mathbf{F}_\delta$	Corrected Decl. 1875. $\mathbf{B}_\delta' = \mathbf{B}_\delta + \mathbf{F}_\delta$	$\delta_0 - B_\delta'$ $\mathbf{V}_\delta$
h m s	s	s		s	s	s
12 18 10.520	+0.331	10.851	0.1	—0.236	10.615	—0.298
18 9.860	+0.252	10.112	0.2	—0.207	9.905	+0.412
18 10.394	+0.044	10.438	2.0	—0.097	10.341	—0.024
18 10.352	+0.059	10.411	2.0	—0.056	10.355	—0.038
18 10.420	—0.075	10.345	1.0	—0.053	10.292	+0.025
18 10.302	+0.051	10.353	0.3	+0.014	10.367	—0.050
18 10.205	+0.044	10.249	1.0	+0.041	10 290	+0.027
18 10.240	+0.041	10.281	1.5	+0.046	10.327	—0.010
18 10.270	+0.042	10.312	2.0	+0.049	10.361	—0.044
18 10.230	—0.003	10.227	3.0	+0.052	10.279	+0.038
18 10.240	.000	10.240	1.0	+0.056	10.296	+0.021
h m s	s	s		s	s	
12 18 10.266	±0.0080	± 0.0101	**14.1**	**—0.0032**	± 0.0004	**6186**
° ′ ″	″	″		″	″	″
26 16 34.40	—1.42	32.98	0 1	+1.18	34.16	—1.27
16 34.90	—2.64	32.26	0.2	+1.03	33.29	—0.40
16 32.77	—1.04	31.73	2.0	+0.48	32.21	+0.68
16 33.29	—0.02	33.27	2.0	+0.28	33.55	—0.66
16 33.87	—1.28	32.59	1.0	+0.26	32.85	+0.04
16 33.06	—0.02	33.04	0.7	—0.19	32.85	+0.04
16 33.30	—0.22	33.08	2.0	—0.25	32.83	+0.06
16 33.20	—0.01	33.19	3.0	—0.26	32.93	—0.04
16 32.70	—0.27	32.97	1.5	—0.28	32.69	+0.20
16 33.30	.00	33.30	1.0	—0.28	33.02	—0.13
26° 16′ 33″.15	±0″.109	± 0″.137	**13.5**	**+0″.016**	± 0″.0051	**6249**

A few observations of other stars were found. I have recorded them here for the sake of completeness. They were not reduced, however, as the resulting positions and proper motions would be entitled to but little confidence, and would be of no value whatever for my purpose.

ADDITIONAL STARS.

No. in Sec. I.	**Authority.**	**Epoch.**	**Right Asc.** at Epoch of Cat.	**Date.**	No. of Obs.	**Declination** at Epoch of Cat.	**Date.**	No. of Obs.
	(13) **B. D. 26°.2330.**							
			h m s			° ′ ″		
5	Bessel (W$_1$.) 284.	1825	12 11 56.00	1831.31	1	26 44 15.5	1831.31	1
26	Paris$_3$ 15108	1875	14 27.83	1873.4	1	27 (36)	—	–
29	A. G. C. 6074	1875	14 27.92	1876.9	2	27 35.8	1876.9	2
	(14) **B. D. 26°.2331 (8 CHASE).**							
			h m s			° ′ ″		
5	Bessel (W$_1$.) 288	1825	12 12 4.38	1831.31	1	26 53 51.2	1831.31	1
29	A. G. C. 6077	1875	14 35.55	1877.3	3	37 13.6	1877.3	3
	(15) **B. D. 26°.2347.**							
			h m s			° ′ ″		
21	Bruxelles 5075	1865	12 18 15.72	1869.37	2	26 18 32.74	1871.63	3
29	A. G. C. 6105	1875	18 46.06	1878.0	6	15 13.1	1878.0	6

The above table is not intended to be exhaustive; it includes only such stars as were found in more than one catalogue. A number of stars, the positions of which are given in the Astronomische Gesellschaft Catalog, and which fall within the limits of my zone, are not mentioned here for the reason stated.

Catalogue of Results.—For convenience, I have collected into a table the final positions and proper motions deduced from the data given on the foregoing pages. The quantities in this table all refer to the epoch 1875; the corresponding quantities for the date of observation T_0, will be found in the Star Tables under the heading "Results." The columns in the "Catalogue" require but little explanation. They are as follows: Col. 1 shows the Name or the B. A. C. or B. D. number of the star; 2 and 3 the Right Ascension and Probable Error in Right Ascension for 1875, respectively; 4 and 5 the *geometric* Precession and Secular Variation respectively; 6 and 7 the Proper Motion in Right Ascension and its Probable Error; 8 the mean Date of Observation, T_0; and 9 the Number of Observations from which the results were obtained. Columns 10 to 17 have the same significance as 2 to 9, but refer to the declination. Column 18 contains Chase's number, and 19 the number assigned by me to the star in question. It should be mentioned, that the declination of B.A.C. 4153 as here given does not include Respighi's observations of that star, which were accidentally overlooked, as the omission was not discovered until all the succeeding calculations had been made. The error introduced thereby is so trifling, however—being only $0''.03$ in the position and $0''.001$ in the proper motion—that I have not deemed it necessary to carry through the correction. The constants of the plates, to compute which these positions are used, would not be changed by doing so. I have, therefore, left the quantities as they were used in the succeeding part of the work, although, of course, the corrected position including Respighi's observations would otherwise have been preferable.

Catalogue of Twelve Stars of the Cluster in

Mean equinox of 1875.0.

Name.	**Right Asc.** at 1875.	Prob. Err. of R. A.	Precess. +	Sec. Var. —	**Prop. Mot.** in R. A.	Prob. Err. of Prop. Mot.	**Date** of Obs.	No. of Obs.
	h m s	s	s	s	s	s		
B. D. 26°.2324	**12 12 22.900**	±0.0146	3.0356	0.0122	**—0.0026**	±0.0010	**1873.63**	**15**
43 Comæ B.	**12 43.731**	±0.0136	3.0349	0.0120	**—0.0049**	±0.0005	**1863.01**	**29**
51 Comæ B.	**14 1.113**	±0.0134	3.0312	0.0119	**—0.0140**	±0.0005	**1864.89**	**38**
B. A. C. 4153	**14 2.520**	±0.0125	3.0300	0.0122	**—0.0071**	±0.0006	**1860.30**	**48**
B. D. 26°.2332	**14 47.387**	±0.0273	3.0294	0.0116	**—0.0016**	±0.0011	**1861.01**	**9**
B. D. 25°.2493	**14 47.581**	±0.0174	3.0307	0.0112	**—0.0166**	±0.0008	**1865.34**	**16**
B. D. 25°.2495	**15 9.118**	±0.0196	3.0298	0.0112	**—0.0032**	±0.0008	**1859.70**	**12**
12 e. Comæ B.	**16 13.202**	±0.0062	3.0250	0.0116	**—0.0022**	±0.0002	**1859.97**	**161**
B. D. 26°.2338	**16 14.293**	±0.0146	3 0250	0.0116	**+0.0004**	±0.0032	**1875.12**	**11**
B. A. C. 4178	**17 46.945**	±0.0109	3.0205	0.0114	**—0.0020**	±0.0005	**1865.15**	**42**
13 f. Comæ B.	**18 2.172**	±0.0081	3.0192	0.0116	**—0.0025**	±0.0002	**1855.01**	**121**
68 Comæ B.	**18 10.266**	±0.0101	3 0200	0.0112	**—0.0032**	±0.0004	**1858.93**	**41**

Coma Berenices from Meridian Observations.

Epoch 1875.0.

Declination at 1875.	Prob Err. of Declin.	Precess. —	Sec. Var. +	**Prop. Mot.** in Decl.	Prob. Err. of Prop. Mot.	**Date** of Obs.	No. of Obs.	Chase's No.	Kretz's No.
26° 52′ 58″.21	±0″.196	20″.025	0″.032	**+0″.086**	±0″.0135	**1873.63**	**15**	2	1
26 42 10.65	±0.173	20.023	0.033	**—0.009**	±0.0069	**1863.17**	**37**	3	2
26 41 42.94	±0.171	20.017	0.036	**+0.030**	±0.0069	**1864.06**	**37**	5	4
27 19 2.26	±0.136	20.017	0.036	**—0.106**	±0.0075	**1863.38**	**83**	6	5
26 24 53.14	±0.317	20.012	0.037	**—0.078**	±0.0146	**1866.30**	**9**	9	8
25 43 14.48	±0.205	20.012	0.037	**+0.144**	±0.0120	**1869.33**	**15**	10	9
25 41 28.01	±0.262	20.010	0.038	**+0.004**	±0.0100	**1856.23**	**15**	11	10
26 32 23.98	±0.074	20.004	0.040	**+0.007**	±0.0028	**1865.03**	**171**	d	14
26 31 20.26	±0.209	20.004	0.040	**+0.088**	±0.0300	**1874.43**	**11**	14	15
26 32 40.72	±0.138	19.994	0.043	**+0.015**	±0.0075	**1867.72**	**49**	18	21
26 47 31.03	±0.107	19.992	0.043	**—0.004**	±0.0035	**1857.40**	**121**	19	22
26 16 33.15	±0.137	19.991	0.044	**+0.016**	±0.0051	**1858.81**	**37**	20	23

PART II.

MEASUREMENT AND REDUCTION OF THE PLATES.

I. The Plates: Description and Measurement.

Description.—The photographs of Coma Berenices were taken with Rutherfurd's large telescope in the years 1870, 1875 and 1876. They differ in no particular from his other star plates. There are always two images of each star, obtained by stopping the driving clock a few seconds after the first exposure had been made, and then starting it again, leaving, meanwhile, the plate in position so that another impression could be made. A third image (or "trail") of the brightest stars is usually found at the distance of about 35 mm. from the second image, obtained in a similar manner, except that the clock was stopped for a longer time than in the previous case. These trails were intended to give an independent means of orienting the plate. I have not used them otherwise than to place the photograph correctly in the measuring machine; for Dr. Schlesinger[1] has shown that no reliance can be placed on the trails for other purposes.

The plates are by no means uniform in quality, some of them giving a much sharper picture than others. Especially noticeable, and at the same time rather annoying, is the elongation of the images on some of the photographs due to irregularities in the clock, which failed to keep pace exactly with the diurnal motion of the stars. Then, again, the number of stars visible on the different plates varies greatly. This is the case even when the exposures were taken on the same night, although these were always of the same length, namely six minutes. The largest number of stars is found on the plates taken in 1875. In spite of their variable quality, however, I decided not to omit any of them, but to measure on each one all the stars that could be plainly seen. This was necessitated by the fact that I had but three plates of the early date; and again but five taken in 1875 and showing a fairly large number of stars. None of these could well be rejected without seriously injuring either the proper motions in the one case, or the positions in the other. But thereby the standard of excellence was placed so low, that none of the others could legitimately be omitted. The result is, that some of the stars show quite large residuals, due to the difficulty of measuring hazy images. Especially is this the case for stars just on the limits of visibility, and for those lying near the edge of the plate, where radial distortion becomes very marked. On the whole, the cluster is not well adapted to photographic measurement, as it is very scattered, and the range of brightness is large.

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[1] "The Præsepe Group, Measurement and Reduction of the Rutherfurd Photographs" by Frank Schlesinger. Annals of the N. Y. Academy of Sciences, Vol. X. The page referred to is 282.

The origin of coördinates was taken to coincide with star 14 (12e Comæ Berenices). For the reduction it is necessary that the point be known approximately where a line from the optical center of the lens strikes the plate perpendicularly. Rutherfurd always so adjusted his instrument, that this line should pass through the image of some bright star, no. 14, in my case.

I subjoin Table I, giving all necessary data regarding the plates. The column "Date" shows the date, and that headed "Sidereal Time," the time of exposure. This latter is the mean of four instants, namely the beginning and end of the first, and the beginning and end of the second exposure. Next follow the reading of the barometer, together with the attached and external thermometers. The 7th and 8th columns refer to the telescope, the former showing the readings of a thermometer in contact with the tube, and the latter the reading of a micrometer head at the eye end. This latter quantity depends on the distance of the plateholder from the object glass, and may bear some relation to the scale value; a question which cannot be settled, however, until many more of the Rutherfurd photographs have been independently reduced. In the last column will be found remarks regarding the quality of the plate, and the number of stars measured.

Table I.—The Plates.

Observatory of Lewis M. Rutherfurd, New York City.

Lat. = 40° 43′ 48″.5 Long. = $4^h\ 55^m\ 56^s.62$ W.

No.	Exposures.		Atmosphere.			Telescope.		Remarks.
	Date.	Sid. Time.	Bar.	Att. Ther.	Ext. Ther.	Ther.	Focus.	
		h m s		°	°	°		
I	1870. April 25.	13 24 08	30.260	53	47	53	8.4	Good; 13 stars.
II	1870. April 25	14 00 05	30.260	53	47	53	8.4	Fair; 17 stars.
III	1870. April 26.	12 20 55	30.200	58	53	58	8.5	Good; 15 stars.
IV	1875. June 2.	14 16 18	30 250	60	56	60	7.7	Good; 20 stars.
V	1875. June 2	14 47 02	30.250	60	56	60	7.7	Good; 18 stars.
VI	1875. June 2.	15 16 32	30.250	60	56	60	7.7	Good; 22 stars.
VII	1875. June 4.	14 43 12	30.250	68	66	70	7.6	Poor; 16 stars.
VIII	1875. June 4.	15 13 02	30.250	68	66	70	7.6	Good; 23 stars.
IX	1876. May 26.	13 27 18	30.136	59	55	60	7.7	V.Good; 14 stars.
X	1876. May 26.	13 55 38	30.136	59	55	60	7.7	Good; 16 stars.
XI	1876. May 26.	14 24 52	30.136	59	55	60	7.7	Good; 16 stars.
XII	1876. May 26.	14 53 32	30 136	59	55	60	7.7	Fair; 16 stars.
XIII	1876. May 27.	13 20 38	30.086	66	63	65	7.65	Poor: 15 stars.
XIV	1876. May 27.	13 51 52	30.086	66	63	65	7.65	Fair; 16 stars.

Measurement.—The fourteen plates were measured during the winters 1896–1897 and 1897–1898, and one of them in the fall of 1898. During the first year, three observers were engaged in the work: Mr. William H. Hays, then graduate student in astronomy, Dr. Schlesinger, and myself; after the spring of 1897 only the latter two remained. In this connection, I wish to thank the two gentlemen, Messrs. Hays and Schlesinger, for their interested and arduous services rendered in my behalf.

The older Repsold measuring machine of the observatory was used throughout. A full description of one of these excellent instruments will be found in Dr. Scheiner's recent work "Die Photographie der Gestirne," p. 148. I shall say only a few words on the subject: The essential features of the machine are a strong iron frame, to which are attached a circular movable plate-holder, and two parallel fixed bridges, one bearing three microscopes and the other a straight scale. The holder is capable of rotation about its centre, and of motion in a direction perpendicular to the bridges. In this motion it is guided by an accurately straight steel cylinder, which is long enough to permit the entire plate to pass underneath the microscope bridge. This latter bears, as already stated, three microscopes. Two of them are permanently fixed to either end, and point at a graduated circle on the circumference of the holder. They contain comb-micrometers, and read to seconds of arc. The third, or measuring microscope, is mounted on a straight guiding-way, and has motion entirely across the plate, in a direction perpendicular to the cylinder. It is evident that any point on the plate may be brought into the field of view. At the left hand end of the bridge is attached a lever arm, by means of which the guiding-way together with the microscope may be raised through a small angle. When in this position, the microscope points at the scale. Readings are made by means of a filar micrometer. This is so arranged, that two revolutions of the screw carry the wires over one division of the scale, *i. e.*, over one millimeter. The head is divided into one hundred parts, so that twothousandths of a millimeter can be read by estimation. As the machine was originally designed for the measurement of réseau plates, the microscope has two screws at right angles to each other; they are designated as the horizontal and the vertical screw respectively.

From the above description of the machine, the method of measuring follows immediately. The microscope being pointed at a star, the micrometer is read; then by means of the lever arm, it is made to point at the scale, and, without moving the microscope itself, the screw is turned until the threads cover the next lower division, and the head is again read. The difference of the two readings, *added* to the number of the line, will give the position of the star with respect to the scale, since the micrometer is so arranged, that the head will show increasing numbers, when the threads are made to move in a direction opposite to increasing numbers on the scale. To measure the plate, then, the following operations were always performed:

Set the plate correctly in the holder, *i. e.*, so, that the measured coördinates will coincide approximately with right ascension and with declination. This is done by first making the line joining the central star with its trail (or third image) parallel to the cylinder, and then turning the plate through 90°, in such a way that the trail shall be *to the right.*[1] Then will the hour angle increase toward the left on the plate, and the direction of a circle of declination will be perpendicular to the scale. Read the graduated circle on both microscopes, observe for runs,[2] and take the temperature. Now measure the position of each star as follows: Point the microscope on the East Image of the star and read the micrometer; point at the scale and read twice on the next lower line; point again on the star and read. Move the microscope so that, the micrometer standing approximately at the same point as before, the wires bisect the West Image. Re-

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[1] NOTE.—It will be seen that this method of orientation involves an error due to the curvature of the path of the central star on the plate, which, for high declinations, becomes large. For a star which describes a small circle in the sky will trace an arc on the photograph, and if the plate is oriented by the method described above, the cylinder will be made parallel to a tangent to this curve at the *middle point* between the central star and its trail, and not, as should be the case, at the star itself. It is easily seen that the value of this error in seconds of arc, $x,''$ is

$$x'' = \tfrac{1}{2} d'' \tan \delta$$

where d'' is the distance in seconds between the central star and its trail (obtained by multiplying the distance in mm. by an approximate scale value) and δ is the declination of that star. If then we move the holder through an angle x'', the plate will be much more accurately oriented and the least square solution for the constants of reduction will be greatly simplified. The sign of this correction will depend on the position of the plate (whether in the northern or in the southern hemisphere), and also on the graduation of the plate-holder. In general it can be determined from the consideration that the true East and West line passes through a point which has an arithmetically smaller declination than the trail. In orienting my plates, I always applied the above correction. The method is due to Dr. Schlesinger.

[2] See Sect. II, "RUNS AND SCREW ERRORS."

peat the operation as for the East Image. Take the mean of the readings on the scale, and subtract from it the mean of the readings on both images. The difference, *divided by 2*, is the distance in millimeters of the *mean* position of the star beyond the given line on the scale. It is designated in the following by $\frac{1}{2} m$. Measure in this way all the stars, beginning with the central. Read the temperature. Remeasure all the stars in the inverse order, with the micrometer head set now at half a revolution from its previous position, in order to eliminate periodic errors of the screw. Read the runs, circles, and temperature.

In this way, on one day, all the stars were measured in one position of the plate. Two observers were always engaged on the work, each one reading all the stars, the runs, and the circles. After completing the measures in one position, the plate is rotated through 90°, and the process is repeated. It is then evident, that if the first position gave differences in right ascension, the second would give differences in declination. Since the two images are separated on the plate by about a millimeter in right ascension, it was in general necessary to use two lines on the scale when measuring that coördinate, while for the other only one was required. In all other respects the measures in both positions are entirely similar. To reduce personality, observations were made with the plate respectively 180° and 270° from its original position, care being taken that the same pair of observers should always read one coördinate in both directions. The greater part of the systematic error, due to the difficulty of judging the center in hazy images, cannot be eliminated by this method, however. The only way to obviate its effect, is to multiply the number of the plates, if that is possible.

In TABLES II and III are recorded all the observational data from which the succeeding reductions are made. TABLE II gives the daily record: It shows the date of measuring the plate, the runs in millimeters on 10 mm. spaces, the circle readings, the mean temperature of the morning, the position of the plate, and the initials of the observers, Schlesinger, Hays or Kretz. The runs as here given are the mean of the two observations taken before and after measuring the stars. The circle readings as recorded show the degrees and minutes of the right hand microscope, while the seconds are the mean of all the readings for the morning. The terms in the fifth column require a little explanation: It has been stated that the normal position for the plate is *trail right.* Measures taken in this position are designated as *x direct.* Counter-clockwise rotation of the holder, which is the direction of increasing numbers on the circle, brings the trails up. Measures in this position are denoted as *y direct.* The meaning of the other terms follows at once. It should be mentioned, that for trail right, right ascension, and for trail up, north polar distance, increase towards the left on the plate, and that the numbers on the scale increase towards the right.

TABLE III gives the uncorrected measured coördinates in terms of the scale-divisions and of ½ *m*, obtained as previously explained. As has been stated, the micrometer could be read by estimation to twothousandths of a millimeter. The mean being taken to one decimal further, unity in the last place of ½ *m* will be a tenth of a micron. This corresponds approximately to 0″.005. The same statement applies to the quantities given in the fifth and ninth columns of the tables. In general it will be found that two lines are given for the x's and one for the y's, agreeing with what has previously been said on this subject. In a few cases a negative sign is attached to ½ *m*: this means that the next higher line on the scale was used. The numbers of the stars in the tables were assigned by me, and increase with the right ascension.

TABLE II.—DAILY RECORDS.

Date, 1897.	Runs in mm.	Circle.	Ther.	Position of Plate.	Obs.
Plate V.					
Jan. 29	—0.0028	181° 28′ 56¾″	64.6	y direct.	K, S
" 30	—0.0030	91 29 2½	64.6	x direct.	S, H
Feb. 1	—0.0020	1 28 56½	68.5	y reversed.	K, S
" 2	—0.0010	271 28 58½	58 9	x reversed.	S, H
Plate I.					
Feb. 20	+0.0028	5° 50′ 0¾″	65.2	x direct.	S, H
" 23	+0.0060	95 49 59¾	65.0	y direct.	K, H
" 24	+0.0018	275 49 59	64.6	y reversed.	K, H
" 25	+0.0055	185 50 0½	63.4	x reversed.	S, H
Plate VI.					
March 9	+0.0065	271° 25′ 7¾″	62.7	x direct.	K, H
" 10	+0.0065	91 25 8	63.6	x reversed.	K, H
" 11	+0.0070	1 25 10¾	62.1	y direct.	S, H
" 12	+0.0015	181 25 9¾	62.1	y reversed.	S, H
Plate IV.					
April 17	+0.0168	91° 42′ 40¼″	65.7	x direct.	S, H
" 19	+0.0152	181 42 40½	64.8	y direct.	K, S
" 20	+0.0170	1 42 38¾	68.1	y reversed.	K, S
" 21	+0.0140	271 42 41	64.8	x reversed.	S, H
Plate VII.					
May 10	+0.0340	181° 22′ 19¼″	71.1	y direct.	K, S
" 11	+0.0340	91 22 21¼	72.5	x direct.	K, S
" 12	+0.0312	1 22 20¾	72 5	y reversed.	K, S
" 18	+0.0325	271 22 18¾	72.5	x reversed.	K, S
Plate IX.					
Dec. 3	—0.0125	87° 01′ 4¾″	66.9	x direct.	K, S
" 4	—0.0110	177 01 4½	64.7	y direct.	K, S
" 7	—0.0128	267 01 5½	66 7	x reversed.	K, S
" 8	—0.0115	357 01 8¼	67.0	y reversed.	K, S
Plate X.					
Dec. 11	—0.0125	266° 57′ 27½″	69.1	x direct.	K, S
" 14	—0.0138	86 57 30¼	64.2	x reversed.	K, S
" 16	—0.0128	356 57 28¾	66.4	y direct.	K, S
" 18	—0.0145	176 57 29¾	65.7	y reversed.	K, S

TABLE II.—(*Continued.*)

Date, 1897–98.	Runs in mm.	Circle	Ther.	Position of Plate.	Obs.
		Plate VIII.			
Dec. 20.	—0.0112	271° 21′ 26¼″	63.5	*x* direct.	K, S
" 21.	—0.0122	1 21 27½	65.6	*y* direct.	K, S
" 23.	—0.0138	91 21 25	65.2	*x* reversed.	K, S
" 24.	—0.0142	181 21 26	61.2	*y* reversed.	K, S
		Plate III.			
Jan. 4	—0.0110	273° 28′ 26¾″	66.2	*x* direct.	K, S
" 5	—0.0110	3 28 24	66.3	*y* direct.	K, S
" 6	—0.0115	93 28 22¾	65.4	*x* reversed.	K, S
" 11	—0.0115	183 28 23	66.3	*y* reversed.	K, S
		Plate XI.			
Jan. 22	—0.0115	267° 23′ 45½″	67.8	*y* reversed.	K, S
" 25	—0.0110	177 23 42¾	65.8	*x* reversed.	K, S
" 27	—0.0110	87 23 40¾	65.8	*y* direct.	K, S
" 29	—0.0118	357 23 44¼	65.5	*x* direct.	K, S
		Plate XII.			
Feb. 1	—0.0125	357° 17′ 10½″	59.1	*x* direct.	K, S
" 2	—0.0135	87 17 7¾	59.0	*y* direct.	K, S
" 3	—0.0105	177 17 7½	59.3	*x* reversed.	K, S
" 4	—0.0120	267 17 7¾	59.6	*y* reversed.	K, S
		Plate XIII.			
Feb. 5	—0.0112	357° 34′ 15¾″	66.6	*x* direct.	K, S
" 8	—0.0115	87 34 14¼	66.7	*y* direct.	K, S
" 9	—0.0102	177 34 16¼	67.9	*x* reversed.	K, S
" 11	—0.0108	267 34 17¼	67.4	*y* reversed.	K, S
		Plate XIV.			
Feb. 16	—0.0115	267° 52′ 37¼″	61.4	*x* direct.	K, S
" 17	—0.0088	87 52 36¼	59.5	*x* reversed.	K, S
" 19	—0.0118	357 52 38	65.3	*y* direct.	K, S
" 22	—0.0112	177 52 35¼	66.0	*y* reversed.	K, S
		Plate II.			
Oct. 28	+0.0030	185° 57′ 42¾″	70.4	*x* direct.	K, S
Nov. 1	+0.0035	275 57 43	69.6	*y* direct.	K, S
" 2	—0.0008	5 57 41½	67.3	*x* reversed.	K, S
" 3	—0.0018	95 57 43	67.8	*y* reversed.	K, S

TABLE III: MEASUREMENTS.—PLATE I.

Star.	Lines.	½ *m.*		*S—H*	Lines.	½ *m.*		*K—H*
		Schles.	Hays.			Kretz.	Hays.	
		x direct.				*y* direct.		
4	94,95	0.8579	0.8598	—0.0019	73	0.9498	0.9482	+0.0016
5	94,95	0.3450	0.3432	+ 18	116	0.3085	0.3049	+ 36
6	88,89	0.1529	0.1504	+ 25	57	0.9234	0.9231	+ 3
7	86,87	0.1874	0.1838	+ 36	68	0.8505	0.8469	+ 36
8	83,84	0.2339	0.2298	+ 41	54	0.8404	0.8398	+ 6
9	83,84	0.2649	0.2621	+ 28	7	0.5781	0.5762	+ 19
10	77,78	0.8001	0.8021	— 20	5	0.5728	0.5715	+ 13
14	61,62	0.4092	0.4072	+ 20	63	0.3152	0.3158	— 6
15	61,62	0.1330	0.1326	+ 4	62	0.1146	0.1151	— 5
21	37,38	0.6348	0.6360	— 12	63	0.6746	0.6749	— 3
22	33,34	0.8319	0.8341	— 22	80	0.5181	0.5142	+ 39
23	31,32	0.6396	0.6378	+ 18	45	0.4046	0.4074	— 28
24	22,23	0.5546	0.5514	+ 32	43	0.9442	0.9442	0
		x reversed.				*y* reversed.		
4	24,23	0.6959	0.6980	—0.0021	45	0.6011	0.6052	—0.0041
5	25,24	0.2126	0.2171	— 45	3	0.2530	0.2545	— 15
6	31,30	0.4008	0.4044	— 36	61	0.6308	0.6295	+ 13
7	33,32	0.3676	0.3701	— 25	50	0.7036	0.7046	— 10
8	36,35	0.3218	0.3184	+ 34	64	0.7136	0.7126	+ 10
9	36.35	0.2922	0.2926	— 4	111	0.9761	0.9775	— 14
10	41,40	0.7552	0.7578	— 26	113	0.9905	0.9900	+ 5
14	58,57	0.1462	0.1459	+ 3	56	0.2334	0.2399	— 65
15	58,57	0.4220	0.4179	+ 41	57	0.4334	0.4339	— 5
21	81,81	0.4200	0.4195	+ 5	55	0.8781	0.8768	+ 13
22	85,84	0.7241	0.7246	— 5	39	0.0398	0.0371	+ 27
23	87,87	0.4181	0.4172	+ 9	74	0.1465	0.1449	+ 16
24	96,96	0.5016	0.5068	— 52	75	0.6101	0.6104	— 3

TABLE III. (*Continued.*)—PLATE II.

Star.	Lines.	½ *m.*		*K—S*	Lines.	½ *m.*		*K—S*
		Kretz.	Schles.			Kretz.	Schles.	
		x direct.				*y* direct.		
1	109,110	0.3222	0.3191	+0.0031	81	0.5651	0.5598	—0.0053
2	104,105	0.1171	0.1114	+ 57	69	0.2782	0.2772	+ 10
4	84,85	0.4978	0.4960	+ 18	68	0.6494	0.6434	+ 60
5	84,84	0.4748	0.4745	+ 3	111	—.0074	—.0030	— 44
6	77,78	0.7951	0.7892	+ 59	52	0.6299	0.6255	+ 44
7	75,76	0.8240	0.8229	+ 11	63	0.5474	0.5496	— 22
8	72,73	0.8641	0.8730	— 86	49	0.5369	0.5378	— 9
9	73,73	0.3951	0.3972	— 21	2	0.2808	0.2796	+ 12
10	67,68	0.4310	0.4328	— 18	0	0.2676	0.2674	+ 2
14	51,52	0.0468	0.0449	+ 19	58	0.0136	0.0139	— 3
15	50,51	0.7680	0.7676	+ 4	56	0.8186	0.8160	+ 26
18	41,42	0.3262	0.3265	— 3	58	0.3715	0.3725	— 10
19	36,36	0.4318	0.4321	— 3	107	—.0388	—.0448	+ 60
21	27,28	0.2705	0.2699	+ 6	58	0.3766	0.3758	+ 8
22	23.24	0.4726	0.4718	+ 8	75	0.2166	0.2164	+ 2
23	21,22	0.2770	0.2750	+ 20	40	0.1081	0.1054	+ 27
24	12,13	0.1865	0.1866	— 1	38	0.6466	0.6449	+ 17
		x reversed.				*y* reversed.		
1	10,9	0.1916	0.1865	+0.0051	37	0.9501	0.9466	+0.0035
2	15,14	0.3998	0.4012	— 14	50	0.2296	0.2289	+ 7
4	34,34	0.5149	0.5112	+ 37	50	0.8618	0.8615	+ 3
5	35,34	0.5352	0.5318	+ 34	8	0.5229	0.5148	+ 81
6	41,40	0.7226	0.7263	— 37	66	0.8845	0.8831	+ 14
7	43,42	0.6872	0.6861	+ 11	56	—.0398	—.0384	— 14
8	46,45	0.6445	0.6374	+ 71	70	—.0260	—.0265	+ 5
9	46,45	0.6137	0.6115	+ 22	117	0.2348	0.2296	+ 52
10	52,51	0.0749	0.0749	0	119	0.2450	0.2431	+ 19
14	68,67	0.4621	0.4608	+ 13	61	0.4900	0.4914	— 14
15	68,67	0.7396	0.7420	— 24	62	0.6924	0.6926	— 2
18	78,77	0.1881	0.1882	— 1	61	0.1391	0.1389	+ 2
19	83,82	0.5800	0.5809	— 9	12	0.5583	0.5582	+ 1
21	92,91	0.2399	0.2405	— 6	61	0.1346	0.1311	+ 35
22	96,95	0.0405	0.0419	— 14	44	0.2921	0.2926	— 5
23	98,97	0.2358	0.2375	— 17	79	0.4069	0.4035	+ 34
24	107,106	0.3200	0.3246	— 46	80	0.8695	0.8689	+ 6

TABLE III. (*Continued.*)—PLATE III.

Star.	Lines.	½ *m.*		*K—S*	Lines.	½ *m.*		*K—S*
		Kretz.	Schles.			Kretz.	Schles.	
		x direct.				*y* direct.		
1	116,116	0.5070	0.5065	+0.0005	85	0.9316	0.9309	+0.0007
2	110,111	0.8131	0.8084	+ 47	73	0.6518	0.6500	+ 18
4	91,92	0.1970	0.1962	+ 8	73	0.0194	0.0180	+ 14
5	90,91	0.6749	0.6722	+ 27	115	0.3639	0.3660	— 21
6	84,85	0.4969	0.4946	+ 23	57	—.0051	—.0054	+ 3
7	82,83	0.5234	0.5195	+ 39	67	0.9208	0.9190	+ 18
8	79,80	0.5730	0.5731	— 1	53	0.9079	0.9082	— 3
9	79,80	0.5951	0.5922	+ 29	6	0.6519	0.6530	— 11
10	74,75	0.1288	0.1288	0	4	0.6448	0.6406	+ 42
14	57,58	0.7422	0.7394	+ 28	62	0.3859	0.3840	+ 19
15	57,58	0.4645	0.4675	— 30	61	0.1888	0.1878	+ 10
21	34,34	0.4712	0.4708	+ 4	62	0.7505	0.7478	+ 27
22	30,31	0.1702	0.1684	+ 18	79	0.5940	0.5902	+ 38
23	28,28	0.4714	0.4679	+ 35	44	0.4828	0.4774	+ 54
24	19,19	0.3875	0.3856	+ 19	43	0.0195	0.0198	— 3
		x reversed.				*y* reversed.		
1	3,2	0.5656	0.5621	+0.0035	33	0.6416	0.6449	—0.0033
2	8,7	0.7625	0.7560	+ 65	45	0.9195	0.9190	+ 5
4	28,27	0.3736	0.3711	+ 25	46	0.5540	0.5538	+ 2
5	28,28	0.3989	0.3935	+ 54	4	0.2090	0.2090	0
6	35,34	0.0826	0.0760	+ 66	62	0.5754	0.5756	— 2
7	36,36	0.5492	0.5460	+ 32	51	0.6492	0.6498	— 6
8	39,39	0.5010	0.4986	+ 24	65	0.6604	0.6605	— 1
9	39,39	0.4818	0.4766	+ 52	112	0.9208	0.9200	+ 8
10	45,44	0.4419	0.4390	+ 29	114	0.9326	0.9286	+ 40
14	61,60	0.8256	0.8236	+ 20	57	0.1814	0.1792	+ 22
15	62,61	0.1035	0 1006	+ 29	58	0.3782	0.3768	+ 14
21	85,84	0.6011	0.5996	+ 15	56	0.8181	0.8159	+ 22
22	89,88	0.4022	0.4001	+ 21	40	—.0210	—.0250	+ 40
23	91,90	0.5974	0.5976	— 2	75	0.0886	0.0876	+ 10
24	100,99	0.6880	0.6824	+ 56	76	0.5479	0.5479	0

TABLE III. (*Continued.*)—PLATE IV.

Star.	Lines.	½ *m.*		*S—H*	Lines.	½ *m.*		*K—S*
		Schles.	Hays.			Kretz.	Schles.	
		x direct.				*y* direct.		
1	118,119	0.4700	0.4716	—0.0016	83	0.2781	0.2758	+0.0023
2	113,114	0.2735	0.2761	— 26	71	—.0101	—.0068	— 33
4	93,94	0.6708	0.6728	— 20	70	0.3578	0.3600	— 22
5	93,94	0.1411	0.1446	— 35	112	0.7045	0.7004	+ 41
6	86,88	0.4535	0.4565	— 30	54	0.3285	0.3298	— 13
7	84,86	0.4828	0.4828	0	65	0.2506	0.2539	— 33
8	81,83	0.5298	0.5262	+ 36	51	0.2400	0.2400	0
9	82,83	0.0775	0.0768	+ 7	4	—.0080	—.0061	— 19
10	76,77	0.5935	0.5918	+ 17	1	0.9744	0.9730	+ 14
11	71,72	0.8395	0.8460	— 65	111	0.6095	0.6126	— 31
12	70,71	0.6272	0.6318	— 46	107	0.5810	0.5826	— 16
13	68,69	0.5621	0.5626	— 5	48	0.8211	0.8216	— 5
14	60,61	0.2109	0.2148	— 39	59	0.7249	0.7219	+ 30
15	59,60	0.9259	0.9291	— 32	58	c.5258	0.5254	+ 4
17	57,58	0.3502	0.3498	+ 4	57	0.0292	0.0296	— 4
18	50,51	0.4846	0.4821	+ 25	60	0.0790	0.0776	+ 14
21	36,37	0.4294	0.4329	— 35	60	0.0844	0.0865	— 21
22	32,33	0.6365	0.6395	— 30	76	0.9259	0.9246	+ 13
23	30,31	0.4354	0.4361	— 7	41	0.8180	0.8156	+ 24
24	21,22	0.3508	0.3486	+ 22	40	0.3479	0.3490	— 11
		x reversed.				*y* reversed.		
1	1,0	0.0846	0.0895	—0.0049	36	0.2765	0.2790	—0.0025
2	6,5	0.2852	0.2871	— 19	48	0.5614	0.5630	— 16
4	25,24	0.8882	0.8919	— 37	49	0.1934	0.1936	— 2
5	26,25	0.4154	0.4218	— 64	6	0.8602	0.8589	+ 13
6	32,31	0.6021	0.6022	— 1	65	0.2199	0.2210	— 11
7	34,33	0.5736	0.5752	— 16	54	0.2955	0.2970	— 15
8	37,36	0.5251	0.5299	— 48	68	0.3081	0.3115	— 34
9	37,36	0.4779	0.4831	— 52	115	0.5664	0.5635	+ 29
10	43,41	0.4641	0.4698	— 57	117	0.5829	0.5851	— 22
11	47,46	0.7145	0.7108	+ 37	7	0.9441	0.9512	— 71
12	49,47	0.4170	0.4244	— 74	12,11	0.4719	0.4751	— 32
13	51,49	0.4945	0.4948	— 3	70	0.7345	0.7340	+ 5
14	59,58	0.3461	0.3482	— 21	59	0.8324	0.8289	+ 35
15	59,58	0.6271	0.6268	+ 3	61	0.0232	0.0246	— 14
17	62,61	0.2054	0.2031	+ 23	62	0.5225	0.5241	— 16
18	69,67	0.5735	0.5744	— 9	59	0.4738	0.4741	— 3
21	83,82	0.1235	0.1282	— 47	59	0.4699	0.4664	+ 35
22	86,85	0.9219	0.9259	— 40	42	0.6320	0.6295	+ 25
23	89,88	0.1218	0.1261	— 43	77	0.7371	0.7379	— 8
24	98,97	0.2104	0.2081	+ 23	79	0.2026	0.2044	— 18

TABLE III. (*Continued.*)—PLATE V.

Star.	Lines.	½ *m*.		*S—H*	Lines.	½ *m*.		*K—S*
		Schles.	Hays.			Kretz.	Schles.	
x direct.					*y* direct.			
1	115,116	0.2261	0.2268	—0.0007	85	0.7595	0.8002	—0.0007
2	109,111	0.5240	0.5236	+ 4	73	0.5135	0.5142	— 7
4	90,91	0.4206	0.4204	+ 2	72	0.8872	0.8888	— 16
5	89,91	0.4045	0.4066	— 21	115	0.2265	0.2236	+ 29
6	83,84	0.6962	0.6939	+ 23	56	0.8581	0.8618	— 37
7	81,82	0.7296	0.7294	+ 2	67	0.7849	0.7885	— 36
8	78,79	0.7772	0.7774	— 2	53	0.7720	0.7732	— 12
9	78,79	0.8032	0.8065	— 33	6	0.5272	0.5360	— 88
10	73,74	0.3180	0.3185	— 5	4	0.5096	0.5076	+ 20
13	65,66	0.3105	0.3055	+ 50	51	0.3511	0.3536	— 25
14	56,58	0.4566	0.4585	— 19	62	0.2589	0.2630	— 41
15	56,57	0.6715	0.6672	+ 43	61	0.0624	0.0628	— 4
18	47,48	0.2350	0.2282	+ 68	62	0.6159	0.6186	— 27
19	41,43	0.3604	0.3534	+ 70	111	0.2069	0.2090	— 21
21	33,34	0.1815	0.1802	+ 13	62	0.6270	0.6274	— 4
22	29,30	0.3908	0.3906	+ 2	79	0.4705	0.4711	— 6
23	27,28	0.1711	0.1735	— 24	44	0.3638	0.3628	+ 10
24	17,19	0.5915	0.5939	— 24	42	0.9019	0.8999	+ 20
x reversed.					*y* reversed.			
1	4,3	0.3330	0.3339	—0.0009	33	0.7594	0.7622	—0.0028
2	9,8	0.5400	0.5378	+ 22	46	0.0390	0.0434	— 44
4	29,27	0.6365	0.6371	— 6	46	0.6656	0.6660	— 4
5	29,28	0.6520	0.6514	+ 6	4	0.3330	0.3359	— 29
6	36,34	0.3590	0.3569	+ 21	62	0.6899	0.6949	— 50
7	37,36	0.8251	0.8231	+ 20	51	0.7635	0.7660	— 25
8	40,39	0.7809	0.7778	+ 31	65	0.7822	0.7830	— 8
9	40,39	0.7532	0.7451	+ 81	113	0.0280	0.0308	— 28
10	46,45	0.2345	0.2326	+ 19	115	0.0494	0.0528	— 34
13	54,53	0.2450	0.2419	+ 31	68	0.1968	0.2010	— 42
14	62,61	0.5984	0.6021	— 37	57	0.2891	0.2915	— 24
15	63,61	0.3809	0.3814	— 5	58	0.4870	0.4908	— 38
18	72,71	0.3238	0.3229	+ 9	56	0.9359	0.9369	— 10
19	77,76	0.6992	0.6949	+ 43	8	0.3502	0.3486	+ 16
21	86,85	0.3746	0.3775	— 29	56	0.9240	0.9221	+ 19
22	90,89	0.1672	0.1664	+ 8	40	0.0851	0.0895	— 44
23	92,91	0.3808	0.3812	— 4	75	0.1881	0.1884	— 3
24	101,100	0.4659	0.4635	+ 24	76	0.6459	0.6496	— 3

TABLE III. (*Continued.*)—PLATE VI.

Star.	Lines.	½ *m.*		*K—H*	Lines.	½ *m.*		*S—H*
		Kretz.	Hays.			Schles.	Hays.	
		x direct.				*y* direct.		
1	108,109	0.4039	0.4035	+0.0004	83	0.3775	0.3790	—0.0015
2	103,104	0.2052	0.2094	— 42	71	0.0911	0.0954	— 43
3	100,101	0.2099	0.2155	— 56	6	0.5601	0.5598	+ 3
4	83,84	0.6019	0.6041	— 22	70	0.4624	0.4628	— 4
5	83.84	0.0738	0.0730	+ 8	112	0.7955	0.8022	— 67
6	76,77	0.8864	0.8860	+ 4	54	0.4332	0.4295	+ 37
7	74 75	0.9162	0.9200	— 38	65	0.3599	0.3596	+ 3
8	72,72	0.4651	0.4605	+ 46	51	0.3445	0.3444	+ 1
9	72,72	0.5165	0.5169	— 4	4	0.1045	0.0974	+ 71
10	66,67	0.5305	0.5314	— 9	2	0.0802	0.0798	+ 4
11	61,62	0.7779	0.7809	— 30	111	0.6935	0.6916	+ 19
12	60,61	0.5730	0.5716	+ 14	107	0.6829	0.6781	+ 48
13	58,59	0.5006	0.4998	+ 8	48	0.9215	0.9231	— 16
14	50.51	0.1418	0.1478	— 60	59	0.8246	0.8249	— 3
15	49,50	0.8639	0.8629	+ 10	58	0.6245	0.6245	0
16	49,49	0.5028	0.5054	— 26	112	0.6254	0.6255	— 1
18	40,41	0.4202	0.4204	— 2	60	0.1758	0.1750	+ 8
19	35,35	0.5236	0.5259	— 23	108	0.7605	0.7596	+ 9
21	26,27	0.3728	0.3754	— 26	60	0.1838	0.1825	+ 13
22	22,23	0.5738	0.5756	— 18	77	0.0212	0.0242	— 30
23	20,21	0.3765	0.3769	— 4	41	0.9145	0.9141	+ 4
24	11,12	0.2912	0.2910	+ 2	40	0.4502	0.4441	+ 61
		x reversed.				*y* reversed.		
1	11,10	0.1544	0.1574	—0.0030	36	0.1738	0.1748	—0.0010
2	16,15	0.3540	0.3584	— 44	48	0.4608	0.4610	— 2
3	19.18	0.3451	0.3430	+ 21	112	1.0018	1.0020	— 2
4	35,35	0.4509	0.4535	— 26	49	0.0911	0.0928	— 17
5	36,35	0.4808	0.4821	— 13	6	0.7624	0.7639	— 15
6	42,41	0.6659	0.6692	— 33	65	0.1210	0.1178	+ 32
7	44,43	0.6381	0.6386	— 5	54	0.1946	0.1928	+ 18
8	47,46	0.5934	0.5925	+ 9	68	0.2096	0.2096	0
9	47,46	0.5404	0.5445	— 41	115	0.4552	0.4605	— 53
10	52,52	0.5254	0.5291	— 37	117	0.4781	0.4802	— 21
11	57.56	0.7724	0.7765	— 41	7	0.8656	0.8702	— 46
12	58,58	0.4824	0.4835	— 11	11	0.8765	0.8738	+ 27
13	60,60	0.5508	0.5525	— 17	70	0.6330	0.6349	— 19
14	69,68	0.4116	0.4149	— 33	59	0.7334	0.7321	+ 13
15	69,68	0.6888	0.6909	— 21	60	0.9284	0.9309	— 25
16	70,69	0.5455	0.5475	— 20	6	0.9312	0.9289	+ 23
18	79.78	0.1361	0.1374	— 13	59	0.3772	0.3775	— 3
19	84.83	0.5319	0.5295	+ 24	10	0.7975	0.7902	+ 73
21	93,92	0.1822	0.1821	+ 1	59	0.3699	0.3740	— 41
22	96.96	0.4872	0.4868	+ 4	42	0.5330	0.5351	— 21
23	99,98	0.1809	0.1839	— 30	77	0.6421	0.6422	— 1
24	108.107	0.2648	0.2669	— 21	79	0.1089	0.1092	— 3

TABLE III. (*Continued.*)—PLATE VII.

Star.	Lines.	½ *m.*		*K—S*	Lines.	½ *m.*		*K—S*
		Kretz.	Schles.			Kretz.	Schles.	
		x direct.				y direct.		
1	118,119	0.7175	0.7142	+0.0033	85	0.9712	0.9705	+0.0007
2	113,114	0.5238	0.5225	+ 13	73	0.6826	0.6838	— 12
4	94,94	0.4214	0.4170	+ 44	73	0.0458	0.0469	— 11
5	93,94	0.3831	0.3849	— 18	115	0.3884	0.3870	+ 14
6	87,88	0.2078	0.2098	— 20	57	0.0156	0.0158	— 2
7	85,86	0.2355	0.2318	+ 37	67	0.9426	0.9434	— 8
8	82,83	0.2759	0.2721	+ 38	53	0.9305	0.9306	— 1
9	82,83	0.3330	0.3280	+ 50	6	0.6925	0.6828	— 3
10	77,77	0.3504	0.3474	+ 30	4	0.6578	0.6596	— 18
14	60,61	0.4558	0.4509	+ 49	62	0.4055	0.4084	— 29
15	60,61	0.1725	0.1729	— 4	61	0.2050	0.2042	+ 8
18	50,51	0.7419	0.7434	— 15	62	0.7575	0.7580	— 5
21	36,37	0.6810	0.6825	— 15	62	0.7646	0.7655	— 9
22	33,33	0.3751	0.3748	+ 3	79	0.6116	0.6068	+ 48
23	30,31	0.6852	0.6844	+ 8	44	0.4926	0.4905	+ 21
24	21,22	0.6051	0.6018	+ 33	43	0.0265	0.0281	— 16
		x reversed.				y reversed.		
1	0,0	0.3394	0.3405	—0.0011	33	0.5938	0.5942	—0.0004
2	5,5	0.5374	0.5376	— 2	45	0.8719	0.8749	— 30
4	25,24	0.6386	0.6395	— 9	46	0.5026	0.5050	— 24
5	26,25	0.1679	0.1718	— 39	4	0.1749	0.1741	+ 8
6	32,31	0.3446	0.3458	— 12	62	0.5366	0.5362	+ 4
7	34,33	0.3240	0.3190	+ 50	51	0.6095	0.6111	— 16
8	37,36	0.2735	0.2774	— 39	65	0.6254	0.6261	— 7
9	37,36	0.2244	0.2209	+ 35	112	0.8749	0.8729	+ 20
10	42,41	0.7056	0.7065	— 9	114	0.9016	0.9016	0
14	58,58	0.6011	0.6032	— 21	57	0.1438	0.1438	0
15	59,58	0.3750	0.3762	— 12	58	0.3458	0.3449	+ 9
18	68,67	0.8122	0.8138	— 16	56	0.7986	0.7960	+ 26
21	82,82	0.3702	0.3689	+ 13	56	0.7929	0.7918	+ 11
22	86,85	0.6841	0.6814	+ 27	39	0.9502	0.9508	— 6
23	88,88	0.3674	0.3689	— 15	75	0.0615	0.0609	+ 6
24	97,97	0.4525	0.4514	+ 11	76	0.5214	0.5212	+ 2

TABLE III. (*Continued.*)—PLATE VIII.

Star.	Lines.	½ *m.*		*K—S*	Lines.	½ *m.*		*K—S*
		Kretz.	Schles.			Kretz.	Schles.	
		x direct.				*y* direct.		
1	116,116	0.5630	0.5622	+0.0008	83	0.6561	0.6550	+0.0011
2	111,111	0.3661	0.3639	+ 22	71	0.3644	0.3656	— 12
4	91,92	0.2635	0.2630	+ 5	70	0.7318	0.7302	+ 16
5	90,91	0.7289	0.7279	+ 10	113	0.0761	0.0705	+ 56
6	84,85	0.5426	0.5419	+ 7	54	0.7049	0.7035	+ 14
7	82,83	0.5731	0.5700	+ 31	65	0.6281	0.6262	+ 19
8	79,80	0.6232	0.6205	+ 27	51	0.6125	0.6106	+ 19
9	79,80	0.6764	0.6710	+ 54	4	0.3662	0.3719	— 57
10	74,75	0.1859	0.1860	— 1	2	0.3440	0.3434	+ 6
11	69,70	0.4272	0.4305	— 33	112	—.0295	—.0312	+ 17
12	68,69	0.2214	0.2188	+ 26	107	0.9535	0.9536	— 1
13	66,67	0.1528	0.1571	— 43	49	0.1891	0.1875	+ 16
14	58,58	0.3009	0.3008	+ 1	60	0.0911	0.0905	+ 6
15	57,58	0.5149	0.5130	+ 19	58	0.8935	0.8932	+ 3
16	56,57	0.6636	0.6616	+ 20	112	0.9059	0.9022	+ 37
17	55,55	0.4411	0.4396	+ 15	57	0.4011	0.4004	+ 7
18	48,48	0.5712	0.5669	+ 43	60	0.4465	0.4464	+ 1
19	42,43	0.6832	0.6829	+ 3	109	0.0374	0.0355	+ 19
20	39,40	0.6126	0.6124	+ 2	111	0.5058	0.5065	— 7
21	34,34	0.5282	0.5285	— 3	60	0.4538	0.4511	+ 27
22	30,31	0.2274	0.2280	— 6	77	0.2902	0.2869	+ 33
23	28,28	0.5291	0.5279	+ 12	42	0.1801	0.1802	— 1
24	19,19	0.4498	0.4492	+ 6	40	0.7191	0.7189	+ 2
		x reversed.				*y* reversed.		
1	3,2	0.5154	0.5120	+0.0034	35	0.9135	0.9139	—0.0004
2	8,7	0.7099	0.7104	— 5	48	0.2021	0.2012	+ 9
4	28,27	0.3111	0.3072	+ 39	48	0.8341	0.8334	+ 7
5	28,28	0.3438	0.3440	— 2	6	0.5039	0.5012	+ 27
6	34,34	0.5342	0.5294	+ 48	64	0.8631	0.8629	+ 2
7	36,36	0.4976	0.4985	— 9	53	0.9394	0.9391	+ 3
8	39,39	0.4492	0.4491	+ 1	67	0.9548	0.9551	— 3
9	39,39	0.3999	0.3996	+ 3	115	0.2030	0.2039	— 9
10	45,44	0.3845	0.3824	+ 21	117	0.2318	0.2305	+ 13
11	50,49	0.1475	0.1406	+ 69	7	0.6089	0.6036	+ 53
12	51,50	0.3524	0.3534	— 10	11	0.6195	0.6176	+ 19
13	53.52	0.4158	0.4142	+ 16	70	0.3818	0.3824	— 6
14	61,60	0.7686	0.7654	+ 32	59	0.4785	0.4756	+ 29
15	61,61	0.5535	0.5546	— 11	60	0.6766	0.6748	+ 18
16	62,62	0.4095	0.4076	+ 19	6	0.6698	0.6732	— 34
17	64,63	0.6312	0.6302	+ 10	62	0.1690	0.1682	+ 8
18	71,70	0.4992	0.4965	+ 27	59	0.1202	0.1214	— 12
19	76,76	0.3894	0.3898	— 4	10	0.5375	0.5334	+ 41
20	79,79	0.4620	0.4609	+ 11	8	0.0681	0.0655	+ 26
21	85,84	0.5440	0.5438	+ 2	59	0.1171	0.1191	— 20
22	89,88	0.3461	0.3421	+ 40	42	0.2828	0.2816	+ 12
23	91,90	0.5451	0.5404	+ 47	77	0.3902	0.3918	— 16
24	100,99	0.6236	0.6238	— 2	78	0.8555	0.8528	+ 27

TABLE III. (*Continued.*)—PLATE IX.

Star.	Lines.	½ *m*.		*K—S*	Lines.	½ *m*.		*K—S*
		Kretz.	Schles.			Kretz.	Schles.	
x direct.					*y* direct.			
1	116,117	0.8440	0.8381	+0.0059	83	0.0719	0.0690	+0.0029
2	111,112	0.6484	0.6488	— 4	70	0.7826	0.7815	+ 11
4	92,92	0.5455	0.5451	+ 4	70	0.1442	0.1461	— 19
5	91,92	0.5022	0.5029	— 7	112	0.4836	0.4836	0
7	83,84	0.3648	0.3585	+ 63	65	0.0386	0.0366	+ 20
8	80,81	0.4150	0.4114	+ 36	51	0.0261	0.0250	+ 11
9	80,81	0.4790	0.4750	+ 40	3	0.7881	0.7878	+ 3
10	75,75	0.4909	0.4880	+ 29	1	0.7564	0.7569	— 5
14	58,59	0.5828	0.5844	— 16	59	0.5016	0.5021	— 5
15	58,59	0.3030	0.3036	— 6	58	0.3018	0.2999	+ 19
21	34,35	0.8115	0.8126	— 11	59	0.8532	0.8526	+ 6
22	31,31	0.5039	0.5036	+ 3	76	0.6914	0.6925	— 11
23	28,29	0.8178	0.8199	— 21	41	0.5868	0.5836	+ 32
24	19,20	0.7445	0.7402	+ 43	40	0.1199	0.1209	— 10
x reversed.					*y* reversed.			
1	2,1	0.7360	0.7349	+0.0011	36	0.5056	0.5059	—0.0003
2	7,7	0.4249	0.4261	— 12	48	0.7891	0.7864	+ 27
4	26,27	0.5279	0.5260	+ 19	49	0.4226	0.4246	— 20
5	27,27	0.5700	0.5678	+ 22	7	0.0984	0.0915	+ 69
7	36,35	0.2141	0.2128	+ 13	54	0.5351	0.5319	+ 32
8	39,38	0.1574	0.1611	— 37	68	0.5480	0.5458	+ 22
9	39,38	0.0960	0.0972	— 12	115	0.7899	0.7875	+ 24
10	44,43	0.5809	0.5815	— 6	117	0.8142	0.8128	+ 14
14	60,60	0.4910	0.4902	+ 8	60	0.0658	0.0691	— 33
15	61,60	0.2688	0.2708	— 20	61	0.2671	0.2688	— 17
21	84,83	0.7565	0.7591	— 26	59	0.7155	0.7139	+ 16
22	88,87	0.5665	0.5669	— 4	42	0.8768	0.8768	0
23	90,89	0.7518	0.7546	— 28	78	—.0170	—.0150	— 20
24	99,98	0.8358	0.8295	+ 63	79	0.4514	0.4506	+ 8

TABLE III. (*Continued.*)—PLATE X.

Star.	Lines.	½ *m.*		*K—S*	Lines.	½ *m.*		*K—S*
		Kretz.	Schles.			Kretz.	Schles.	
	x direct.				*y* direct.			
1	113,114	0.3234	0.3208	+0.0026	86	0.2979	0.2959	+0.0020
2	108,109	0.1272	0.1304	— 32	74	0.0085	0.0106	— 21
4	88,89	0.5262	0.5255	+ 7	73	0.3750	0.3754	— 4
5	88,88	0.4890	0.4862	+ 28	115	0.7070	0.7061	+ 9
6	81,82	0.8085	0.8068	+ 17	57	0.3482	0.3474	+ 8
7	79,80	0.8375	0.8365	+ 10	68	0.2682	0.2675	+ 7
8	76,77	0.8894	0.8885	+ 9	54	0.2530	0.2508	+ 22
9	77,77	0.4504	0.4506	— 2	7	0.0102	0.0132	— 30
10	71,72	0.4591	0.4592	— 1	5	—.0132	—.0114	— 18
14	55,56	0.0611	0.0642	— 31	62	0.7330	0.7338	— 8
15	54,55	0.7846	0.7838	+ 8	61	0.5306	0.5309	— 3
18	45,46	0.3384	0.3440	— 56	63	0.0811	0.0808	+ 3
21	31,32	0.2909	0.2924	— 15	63	0.0885	0.0886	— 1
22	27,28	0.4865	0.4858	+ 7	79	0.9278	0.9288	— 10
23	25,26	0.2966	0.2974	— 8	44	0.8208	0.8199	+ 9
24	16,17	0.2174	0.2150	+ 24	43	0.3552	0.3589	— 37
	x reversed.				*y* reversed.			
1	6,5	0.2449	0.2476	—0.0027	33	0.2816	0.2811	+0.0005
2	11,10	0.4430	0.4445	— 15	45	0.5610	0.5622	— 12
4	31,30	0.0442	0.0449	— 7	46	0.1946	0.1944	+ 2
5	31,30	0.5838	0.5861	— 23	3	0.8681	0.8685	— 4
6	37,36	0.7638	0.7629	+ 9	62	0.2221	0.2238	— 17
7	39,38	0.7318	0.7322	— 4	51	0.3011	0.3025	— 14
8	42,41	0.6811	0.6792	+ 19	65	0.3166	0.3186	— 20
9	42,41	0.6245	0.6168	+ 77	112	0.5606	0.5620	— 14
10	48,47	0.1142	0.1102	+ 40	114	0.5840	0.5858	— 18
14	64,63	0.5032	0.5032	0	56	0.8351	0.8361	— 10
15	64,63	0.7844	0.7795	+ 49	58	0.0371	0.0371	0
18	74,73	0.2335	0.2320	+ 15	56	0.4891	0.4886	+ 5
21	88,87	0.2800	0.2806	— 6	56	0.4802	0.4796	+ 6
22	92,91	0.0872	0.0886	— 14	39	0.6421	0.6435	— 14
23	94,93	0.2758	0.2776	— 18	74	0.7484	0.7470	+ 14
24	103,102	0.3649	0.3592	+ 57	76	0.2141	0.2148	— 7

TABLE III. (*Continued.*)—PLATE XI.

Star.	Lines.	½ *m.*		*K—S*	Lines.	½ *m.*		*K—S*
		Kretz.	Schles.			Kretz.	Schles.	
		x direct.				y direct.		
1	115,116	0.1050	0.0976	+0.0074	85	0.6549	0.6510	+0.0039
2	109,110	0.9070	0.9062	+ 8	73	0.3641	0.3659	— 18
4	90,91	0.3026	0.3010	+ 16	72	0.7310	0.7299	+ 11
5	89,90	0.7635	0.7664	— 29	115	0.0649	0.0631	+ 18
6	83,84	0.5946	0.5905	+ 41	56	0.7060	0.7035	+ 25
7	81,82	0.6135	0.6128	+ 7	67	0.6280	0.6298	— 18
8	78,79	0.6694	0.6629	+ 65	53	0.6142	0.6096	+ 46
9	78,79	0.7289	0.7264	+ 25	6	0.3726	0.3706	+ 20
10	73,74	0.2374	0.2331	+ 43	4	0.3458	0.3455	+ 3
14	56,57	0.8426	0.8400	+ 26	62	0.0909	0.0894	+ 15
15	56,57	0.5632	0.5659	— 27	60	0.8961	0.8946	+ 15
18	47,48	0.1231	0.1212	+ 19	62	0.4459	0.4438	+ 21
21	33,34	0.0709	0.0698	+ 11	62	0.4491	0.4464	+ 27
22	29,30	0.2689	0.2655	+ 34	79	0.2870	0.2869	+ 1
23	27,28	0.0744	0.0746	— 2	44	0.1779	0.1772	+ 7
24	18,19	—.0016	—.0060	+ 44	42	0.7154	0.7159	— 5
		x reversed.				y reversed.		
1	4,3	0.4698	0.4730	—0.0032	33	0.9211	0.9220	—0.0009
2	9,8	0.6674	0.6631	+ 43	46	0.2062	0.2078	— 16
4	29,28	0.2696	0.2675	+ 21	46	0.8368	0.8405	— 37
5	29,28	0.8052	0.8049	+ 3	4	0.5128	0.5100	+ 28
6	36,35	—.0194	—.0211	+ 17	62	0.8656	0.8645	+ 11
7	38,36	0.4594	0.4579	+ 15	51	0.9416	0.9402	+ 14
8	40,39	0.9111	0.9076	+ 35	65	0.9599	0.9572	+ 27
9	40,39	0.8484	0.8425	+ 59	113	0.2010	0.2010	0
10	46,45	0.3371	0.3342	+ 29	115	0.2256	0.2248	+ 8
14	62,61	0.7290	0.7235	+ 55	57	0.4795	0.4734	+ 61
15	63,62	0.0098	0.0035	+ 63	58	0.6739	0.6721	+ 18
18	72,71	0.4490	0.4468	+ 22	57	0.1256	0.1246	+ 10
21	86,85	0.5012	0.5011	+ 1	57	0.1218	0.1222	— 4
22	90,89	0.3050	0.3014	+ 36	40	0.2834	0.2808	+ 26
23	92,91	0.4932	0.4959	— 27	75	0.3880	0.3895	— 15
24	101,100	0.5831	0.5762	+ 69	76	0.8542	0.8540	+ 2

TABLE III. (*Continued.*)—PLATE XII.

Star.	Lines.	½ *m.*		*K—S*	Lines.	½.*m.*		*K—S*
		Kretz.	Schles.			Kretz.	Schles.	
		x direct.				y direct.		
1	117,117	0.3558	0.3552	+0.0006	85	0.6570	0.6552	+0.0018
2	111,112	0.6516	0.6536	— 20	73	0.3662	0.3661	+ 1
4	92,92	0.5559	0.5545	+ 14	72	0.7385	0.7341	+ 44
5	91,92	0.5270	0.5298	— 28	115	0.0692	0.0678	+ 14
6	85,86	0.3406	0.3415	— 9	56	0.7066	0.7070	— 4
7	83,84	0.3695	0.3665	+ 30	67	0.6330	0.6314	+ 16
8	80,81	0.4196	0.4185	+ 11	53	0.6179	0.6179	0
9	80,81	0.4741	0.4686	+ 55	6	0 3818	0.3781	+ 37
10	75,75	0.4812	0.4772	+ 40	4	0.3498	0.3501	— 3
14	58,59	0.5935	0.5900	+ 35	62	0.0949	0.0946	+ 3
15	58,59	0.3138	0.3139	— 1	60	0.8989	0.8996	— 7
18	49,49	0.3775	0.3780	— 5	62	0.4556	0.4524	+ 32
21	34,35	0.8196	0.8184	+ 12	62	0.4604	0.4576	+ 28
22	31,31	0.5218	0.5176	+ 42	79	0.2939	0.2960	— 21
23	28,29	0.8182	0.8201	— 19	44	0.1931	0.1894	+ 37
24	19,20	0.7440	0.7414	+ 26	42	0.7256	0.7276	— 20
		x reversed.				y reversed.		
1	2,1	0.7130	0.7108	+0.0022	33	0.9225	0.9211	+0.0014
2	7,7	0.4231	0.4170	+ 61	46	0.2075	0.2051	+ 24
4	27,26	0.5166	0.5126	+ 40	46	0.8381	0.8351	+ 30
5	27,27	0.5425	0.5418	+ 7	4	0.5074	0.5026	+ 48
6	34,33	0.2350	0.2334	+ 16	62	0.8635	0.8622	+ 13
7	36,35	0.2072	0.2038	+ 34	51	0.9378	0.9370	+ 8
8	39,38	0.1575	0.1542	+ 33	65	0.9532	0.9520	+ 12
9	39,38	0.1039	0.0998	+ 41	113	0.2014	0.1956	+ 58
10	44,43	0.5919	0.5888	+ 31	115	0.2255	0.2234	+ 21
14	60,60	0.4779	0.4751	+ 28	57	0.4702	0.4686	+ 16
15	61,60	0.2556	0.2520	+ 36	58	0.6709	0.6696	+ 13
18	70,69	0.6935	0.6954	— 19	57	0.1172	0.1170	+ 2
21	84,83	0.7489	0.7474	+ 15	57	0.1140	0.1115	+ 25
22	88,87	0.5515	0.5468	+ 47	40	0.2756	0.2738	+ 18
23	90,89	0.7484	0.7478	+ 6	75	0.3842	0.3832	+ 10
24	99,98	0.8322	0.8305	+ 17	76	0.8444	0.8439	+ 5

TABLE III. (*Continued.*)—PLATE XIII.

Star.	Lines.	½ *m.*		*K—S*	Lines.	½ *m.*		*K—S*
		Kretz.	Schles.			Kretz.	Schles.	
		x direct.				*y* direct.		
1	117,118	0.1521	0.1500	+0.0021	84	0.4056	0.4038	+0.0018
2	112,112	0.4571	0.4561	+ 10	72	0.1191	0.1161	+ 30
4	92,93	0.3555	0.3516	+ 39	71	0.4829	0.4791	+ 38
5	91,92	0.8075	0.8118	— 43	113	0.8171	0.8115	+ 56
6	85,86	0.6416	0.6390	+ 26	55	0.4538	0.4540	— 2
7	83,84	0.6654	0.6639	+ 15	66	0.3712	0.3728	— 16
8	80,81	0.7216	0.7218	— 2	52	0.3614	0.3610	+ 4
9	80,81	0.7885	0.7866	+ 19	5	0.1211	0.1236	— 25
10	75,76	0.2985	0.2965	+ 20	3	0.0934	0.1000	— 66
14	58,59	0.8888	0.8861	+ 27	60	0.8355	0.8332	+ 23
15	58,59	0.6098	0.6134	— 36	59	0.6378	0.6356	+ 22
21	35,36	0.1186	0.1189	— 3	61	0.1895	0.1888	+ 7
22	31,32	0.3111	0.3119	— 8	78	0.0312	0.0274	+ 38
23	29,30	0.1250	0.1258	— 8	42	0.9195	0.9172	+ 23
24	20,21	0.0474	0.0486	— 12	41	0.4536	0.4536	0
		x reversed.				*y* reversed.		
1	2,1	0.4248	0.4224	+0.0024	35	0.1695	0.1682	+0.0013
2	7,6	0.6190	0.6181	+ 9	47	0.4578	0.4562	+ 16
4	27,26	0.2204	0.2159	+ 45	48	0.0898	0.0899	— 1
5	27,26	0.7622	0.7606	+ 16	5	0.7630	0.7619	+ 11
6	33,33	0.4400	0.4396	+ 4	64	0.1200	0.1222	— 22
7	35,35	0.4100	0.4096	+ 4	53	0.2000	0.2028	— 28
8	38,37	0.8515	0.8515	0	67	0.2120	0.2121	— 1
9	38,37	0.7888	0.7854	+ 34	114	0.4490	0.4478	+ 12
10	44,43	0.2812	0.2770	+ 42	116	0.4812	0.4779	+ 33
14	60,59	0.6799	0.6775	+ 24	58	0.7315	0.7308	+ 7
15	60,60	0.4586	0.4592	— 6	59	0.9350	0.9342	+ 8
21	84,83	0.4496	0.4502	— 6	58	0.3815	0.3799	+ 16
22	88,87	0.2611	0.2592	+ 19	41	0.5430	0.5421	+ 9
23	90,89	0.4429	0.4445	— 16	76	0.6502	0.6499	+ 3
24	99,98	0.5315	0.5289	+ 26	78	0.1174	0.1174	0

TABLE III. (*Continued.*)—PLATE XIV.

Star.	Lines.	½ *m.*		*K—S*	Lines.	½ *m.*		*K—S*
		Kretz.	Schles.			Kret2.	Schles.	
		x direct.				*y* direct.		
1	113,114	0.2245	0.2214	+0.0031	84	0.9181	0.9144	+0.0037
2	108,108	0.5280	0.5268	+ 12	72	0.6308	0.6332	— 24
4	88,89	0.4256	0.4272	— 16	72	—.0031	—.0052	+ 21
5	87,88	0.8855	0.8874	— 19	114	0.3274	0.3272	+ 2
6	81,82	0.7135	0.7152	— 17	56	—.0285	—.0284	— 1
7	79,80	0.7394	0.7440	— 46	66	0.8921	0.8905	+ 16
8	76,77	0.7885	0.7918	— 33	52	0.8752	0.8766	— 14
9	76,77	0.8565	0.8554	+ 11	5	0.6408	0.6402	+ 6
10	71,72	0.3648	0.3628	+ 20	3	0.6086	0.6088	— 2
14	55,55	0.4655	0.4644	+ 11	61	0.3536	0.3556	— 20
15	54,55	0.6892	0.6925	— 33	60	0.1579	0.1568	+ 11
18	45,46	0.2465	0.2452	+ 13	61	0.7085	0.7068	+ 17
21	31,32	0.1939	0.1910	+ 29	61	0.7102	0.7105	— 3
22	27,28	0.3870	0.3869	+ 1	78	0.5519	0.5500	+ 19
23	25,26	0.1961	0.1980	— 19	43	0.4438	0.4404	+ 34
24	16,17	0.1186	0.1204	— 18	42	—.0202	—.0190	— 12
		x reversed.				*y* reversed.		
1	6,5	0.3469	0.3476	—0.0007	34	0.6566	0.6596	—0.0030
2	11,10	0.5432	0.5428	+ 4	46	0.9399	0.9405	— 6
4	31,30	0.1449	0.1436	+ 13	47	0.5769	0.5765	+ 4
5	31,30	0.6825	0.6811	+ 14	5	0.2490	0.2472	+ 18
6	37,36	0.8592	0.8519	+ 73	63	0.6041	0.5984	+ 57
7	39,38	0.8290	0.8301	— 11	52	0.6828	0.6811	+ 17
8	42,41	0.7812	0.7808	+ 4	66	0.6966	0.6958	+ 8
9	42,41	0.7201	0.7168	+ 33	113	0.9422	0.9371	+ 51
10	48,47	0.2098	0.2056	+ 42	116	—.0358	—.0384	+ 26
14	64,63	0.6045	0.6021	+ 24	58	0.2125	0.2099	+ 26
15	64,64	0.3796	0.3812	— 16	59	0.4166	0.4150	+ 16
18	74,73	0.3269	0.3275	— 6	57	0.8676	0.8644	+ 32
21	88,87	0.3771	0.3801	— 30	57	0.8635	0.8602	+ 33
22	92,91	0.1838	0.1869	— 31	41	0.0238	0.0232	+ 6
23	94,93	0.3729	0.3749	— 20	76	0.1311	0.1312	— 1
24	103,102	0.4605	0.4579	+ 26	77	0.5959	0.5958	+ 1

II. Instrumental Corrections.

Division Errors.—The measured coördinates of any star are the difference in the readings on the scale corresponding to the central star, and those corresponding to the star in question. Hence they depend directly on the distance between two given lines on the scale. If this were perfect, an equal number of divisions would represent exactly the same length, no matter what part of the scale were used. That is not the case however, and corrections must therefore be applied to the different lines, so as to reduce all measured distances to a common unit. The unit selected was 1/130th of the total length, that being the number of spaces into which the scale is divided. Each space equals approximately one millimeter.

In the winter of 1896–1897, the scale used for all the Coma measurements was carefully investigated for division errors, Professor Jacoby's method, described by him in the *American Journal of Science*, Vol. I, 1896, p. 333, being followed throughout. The details of the investigation are to be published at a later date by the observatory; I shall give here merely a table of results. A determination of the errors had been made previous to shipping the scale to America, by the *Kaiserliche Normal Aichungs Kommission*, at Berlin. Their results are published in the *Annals of the New York Academy of Sciences*, Vol. IX, p. 206. I decided to exclude them, however, as it was deemed most accurate to use only those results which had been obtained under the same conditions and with the same instrument as all the other observations employed in the reductions. Nor were the quantities as used greatly affected thereby, for the two determinations agree quite well, differing in no case by more than 0″.11. As each star was made to depend on a number of lines, the error introduced by using an inaccurate value of the division errors was still further reduced.

In the table on p. 423 the corrections, which must be added to the measured ½ *m.* with the sign shown, are given in millimeters. The argument is the number of the line. When two lines were used, the mean of the corresponding corrections was applied to ½ *m.*

Corrections for Runs and Screw Errors.—As has already been stated, observations were made for runs twice a day, once by each observer. A complete observation always consisted of two determinations, made as follows: The screw being set at about 5 *R* (the *R* representing revolutions), the spider-threads were set on the line 70, and the micrometer head was read. Then, without moving the microscope, the screw was turned until the threads bisected line 65, and a reading was taken. Then once more on 65, and back to 70, and the observation was completed. The lines 65 and 70 were selected as they have nearly the same division errors. Since the screw makes two complete revolutions while the threads cover the distance of one millimeter on the scale, and since the screw readings increase when the threads are moved in a direction opposite to that of increasing numbers on the scale, it is evident, that, if it were not for runs, the readings on line 70 would be less than those on line 65 by exactly 10 *R*. If that is not the case, then the correction to be added to any observed ½ *m* in order to reduce it to the case of no runs of the screw, is

$$-(\tfrac{1}{2}m)\frac{r}{5}\text{ millimeters,}$$

where

$$2r = \text{Read. on line } 65 - \text{Read. on line } 70 - 10R.$$

Thus $2r$ is the total error of runs on ten revolutions; for each day of observation it is evidently equal numerically to the "Runs in mm." of TABLE II. For one millimeter the error will evidently be $\tfrac{1}{2}\cdot 2r/5$, the factor ½ reducing the quotient to mm. And since the correction to each ½ *m* must be proportional to

TABLE IV.—DIVISION ERRORS OF THE SCALE.

Line.	Correction in mm.	Line.	Correction in mm.	Line.	Correction in mm.
0	0.0000	44	+0.0029	88	+0.0025
1	+0.0011	45	+0.0020	89	+0.0026
2	—0.0007	46	+0.0021	90	+0.0018
3	—0.0001	47	+0.0006	91	+0.0027
4	+0.0002	48	+0.0013	92	+0.0025
5	—0.0004	49	+0.0015	93	+0.0026
6	+0.0001	50	+0.0007	94	+0.0026
7	—0.0013	51	+0.0018	95	+0.0026
8	—0.0008	52	+0.0030	96	+0.0019
9	—0.0009	53	+0.0024	97	+0.0008
10	—0.0001	54	+0.0032	98	+0.0014
11	+0.0014	55	+0.0028	99	+0.0004
12	+0.0006	56	+0.0030	100	+0.0019
13	+0.0014	57	+0.0034	101	+0.0004
14	+0.0016	58	+0.0038	102	—0.0005
15	+0.0015	59	+0.0034	103	+0.0002
16	+0.0009	60	+0.0034	104	+0.0014
17	+0.0008	61	+0.0038	105	+0.0009
18	+0.0012	62	+0.0044	106	+0.0012
19	+0.0012	63	+0.0058	107	+0.0002
20	+0.0007	64	+0.0050	108	+0.0012
21	+0.0015	65	+0.0053	109	.0000
22	+0.0016	66	+0.0059	110	—0.0002
23	+0.0014	67	+0.0050	111	+0.0002
24	+0.0012	68	+0.0052	112	—0.0006
25	+0.0007	69	+0.0057	113	—0.0013
26	+0.0026	70	+0.0054	114	+0.0005
27	+0.0033	71	+0.0056	115	—0.0003
28	+0.0026	72	+0.0047	116	.0000
29	+0.0020	73	+0.0046	117	+0.0020
30	+0.0035	74	+0.0047	118	+0.0022
31	+0.0030	75	+0.0037	119	+0.0026
32	+0.0022	76	+0.0052	120	+0.0021
33	+0.0024	77	+0.0045	121	+0.0014
34	+0.0013	78	+0.0041	122	+0.0024
35	+0.0032	79	+0.0040	123	+0.0015
36	+0.0024	80	+0.0033	124	+0.0024
37	+0.0025	81	+0.0043	125	+0.0012
38	+0.0016	82	+0.0029	126	+0.0018
39	+0.0025	83	+0.0050	127	+0.0014
40	+0.0033	84	+0.0034	128	+0.0005
41	+0.0020	85	+0.0021	129	+0.0015
42	+0.0025	86	+0.0014	130	.0000
43	+0.0024	87	+0.0026		

that quantity, the above formula follows at once. Tables with the argument $\frac{1}{2}m$ may evidently be constructed giving the corrections corresponding to any value of $2r$.

Before proceeding to do so, however, let us consider the errors of the screw. These are of two kinds, periodic and non-periodic. The former were eliminated during the measurement by always setting the screw to a certain reading (usually $9R$) when pointing at a star during the first half of the day's work, and then, upon reversing the operation, setting it always at a reading differing from the former by $0.5R$. Thus each star was read with the screw in both positions. In order to obviate the effects of non-uniformity of pitch, certain corrections must be applied, however. Investigation showed these to be:

	Corrections in Millimeters.	
Reading of Micrometer Head.	Vertical Screw.	Horizontal Screw.
$5R$	0.0000	0.0000
6	+0.0004	+0.0005
7	+0.0004	+0.0002
8	—0.0002	—0.0003
9	—0.0007	—0.0012
10	—0.0014	—0.0017
11	—0.0020	—0.0022
12	—0.0024	—0.0021
13	—0.0023	—0.0022
14	—0.0013	—0.0014
15	0.0000	0.0000

The above quantities are in mm. and must be added to the readings. The vertical screw was used for one plate only, No. II; the following discussion applies to it as well as to the horizontal screw, *mutatis mutandis*.

It will be seen that between $9R$ and $11R$ the increase in the correction is proportionate to the distance from $9R$. Hence if we start our measures of any star with the original setting of the micrometer head at $9R$, then the increase in the correction will be proportionate to $\frac{1}{2}m$, remembering that the maximum value $\frac{1}{2}m$ can have is 1.0, which corresponds to $2R$. This was always done except in certain cases to be mentioned later. As the coördinates are the difference between the readings on the stars and the readings on the central taken on the same day, we may, without affecting the final results, subtract a constant from the screw correction. Taking, then, the zero point at 9*R*, and as our argument tenths of millimeters (or fifths of a revolution) beyond 9*R*, we get the following table for correcting the readings of the horizontal screw :

Reading of Head.	Corresp. ½*m*.	Corresp. Correction.
9.0	0.0	0.0000
9.2	0.1	—0.0001
9.4	0.2	—0.0002
9.6	0.3	—0.0003
9.8	0.4	—0.0004
10.0	0.5	—0.0005
10.2	0.6	—0.0006
10.4	0.7	—0.0007
10.6	0.8	—0.0008
10.8	0.9	—0.0009
11.0	1.0	—0.0010

During the second half of a day's work, the initial setting on the star was usually 9.5*R*. As a result, the readings on the scale sometimes fell beyond 11*R*. For such cases the above table will no longer apply as it stands, for the correction beyond 11*R* does not bear the same proportion to ½ *m* as holds below that point. We may, however, construct a table similar to the preceding, but differing in the last figures. For, all the stars being again measured beginning always at the same point on the screw, we may, as before, subtract a constant from the screw corrections. We obtain thus the table :

Reading of Head.	Corresponding ½ *m*.	Corresponding Correction.
9.5	0.0	—0.0000
9.7	0.1	—0.0001
9.9	0.2	— 0.0002
10.1	0.3	—0.0003
10.3	0.4	—0.0004
10.5	0.5	—0.0005
10.7	0.6	—0.0006
10.9	0.7	—0.0007
11.1	0.8	—0.00074
11.3	0.9	—0.00072
11.5	1.0	—0.00070

One plate was measured, beginning with $8.7R$ during the first half, and $9.2R$ during the second half of each morning's work. This required the construction of a third table. The method was entirely similar to the above, so that I need not enter on it here.

In the foregoing it has been shown that the screw correction may be put in a form to be directly proportionate to $\frac{1}{2}m$. But we have seen previously, that, from the nature of things, the correction for runs is proportionate to the same quantity. We can therefore construct a table with the argument $\frac{1}{2}m$, which will give at once the combined effect of both corrections. For example, let us consider the case of Dec. 14th, 1897. From Table II we find that $2r$ on that date was -0.0069 mm., *i. e.*, the means of the four differences

$$\text{Read. on } 65 - \text{Read. on } 70 - 10R$$

was -0.0069 mm. The screw therefore *registers* less than the true distance, and a certain quantity must be added to each $\frac{1}{2}m$. By the general formula this quantity is

$$(\tfrac{1}{2}m) \times 0.0138/10 \text{ millimeters.}$$

Giving $\frac{1}{2}m$ the values 0.1, 0.2 . . . 1.0, and combining with the corresponding screw corrections, we get the table

$\frac{1}{2}m$.	Beginning at 9.0	Beginning at 9.5
0.0	+ 0.00000	+ 0.00000
0.1	.00004	.00004
0.2	.00008	.00008
0.3	.00011	.00011
0.4	.00015	.00015
0.5	.00019	.00019
0.6	.00023	.00023
0 7	.00027	.00027
0.8	.00030	.00036
0.9	.00034	.00052
1.0	.00038	.00068

Tables like the specimen were constructed for each observed value of the runs. The columns headed "Beginning at 9.0" and "Beginning at 9.5" give the corrections in mm., to be applied to the measured $\frac{1}{2}$ m's. They refer respectively to the first and to the second half of the morning's work. One point regarding the use of these tables deserves mention: It sometimes happens that the reading on the scale corresponding to one image of a star is less, and that corresponding to the other image is greater than $11R$. In such cases the correction must be found from the table separately for each reading, and then the mean of the two taken. This is evident if we remember the way in which $\frac{1}{2}m$ is obtained.

Measured Coördinates and Rotation Errors.—Having applied the corrections described above, we are in position to obtain the measured coördinates. These are the differences of the readings on a star and the readings on the central star, *i. e.*, star No. 14. As the x is to be positive when the star has a greater right ascension, and the y is to be positive when it has a greater declination (algebraically) than the central, we must apply the following rule: Subtract the position of the star from that of the central for x *direct*, and subtract the central from the star for y *direct*. For the opposite positions of the plate these operations must, of course, be reversed. The reasons for this rule are plain, when we remember that the numbers on the scale increase towards the right.

The coördinates thus obtained are not yet free from error, however. For it is evident that, unless the plate were always rotated exactly 90° from its previous position, the axes of reference would not be rectangular. This was, however, found to be impossible of accomplishment. The best that could be done was to turn the plate approximately 90°, and then to measure exactly the angle through which it had been rotated. In order to obtain formulæ to reduce the measured coördinates to what they should have been, let us call

x', y' the coördinates referred to the central star as measured;
x, y the same coördinates as they should be;
OX' OY' the position the axes actually had on the plate;
OX, OY the position they should have had;

θ the angle XOX', positive if the plate must be turned counter-clockwise in order to make OX and OX' coincide. Then the positive OX' will fall between positive OX and OY, for, *on the plate*, positive coördinates correspond to the usual position of the axes, *i. e.*, positive x to the right, and positive y up, when the trail is left (corresponding to x *reversed*).

Let also x_0', y_0'; x_0, y_0 be the coördinates of the central star referred to the center of rotation, *o*, corresponding to the actual and to the corrected position of the plate respectively.

Then by the usual formulæ for the transformation of coördinates, we have

$$x_0 + x = (x_0' + x') \cos\theta - (y_0' + y') \sin\theta$$
$$y_0 + y = (x_0' + x') \sin\theta + (y_0' + y') \cos\theta$$

or expanding and remembering that

$$x_0 = x_0' \cos\theta - y_0' \sin\theta$$
$$y_0 = x_0' \sin\theta + y_0' \cos\theta$$

and that θ is very small, we find

$$x = x' - y'.\ \theta'' \sin 1''$$
$$y = y' + x'.\ \theta'' \sin 1''$$

i. e., from the measured x' we must subtract $y'.\ \theta'' \sin 1''$ and to the measured y' we must add $x'.\ \theta'' \sin 1''$ in order to obtain the correct coördinates.[1] It will be seen that these formulæ take account of the fact that the center of rotation of the plate does not coincide in position with the origin of coördinates.

To determine what sign to give θ'' in any special case, we need but remember that in the Repsold measuring machine an increase in angle corresponds to positive (counter-clockwise) rotation of the plate. Hence if we let

Q = the seconds of the circle reading to which all the positions are to be reduced;

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[1] See in this connection Harold Jacoby, "Permanence of the Rutherfurd Photographic Plates," Annals New York Academy of Sciences, Vol. IX, p. 267, where the same formulæ are given.

Q' = the seconds actually read on the circles at any given date, then will the equation

$$Q - Q' = \theta''$$

give θ'' with the sign with which it is to be used in the formulæ.

Tables can, of course, be constructed for any value of θ'', having as argument distances in millimeters. This has been done and by their aid the measured coördinates have been reduced to the position of rectangular axes. The values of Q used were as follows (Q need not, of course, be any one of the readings; it is best taken so as to make the corrections as small as possible).

Plate I	$Q = 60''$
II	$43''$
III	$23''$
IV	$40''\frac{1}{2}$
V	$58''\frac{1}{2}$
VI	$9''\frac{3}{4}$
VII	$20''\frac{3}{4}$
VIII	$26''$
IX	$5''\frac{1}{2}$
X	$29''\frac{3}{4}$
XI	$44''\frac{1}{4}$
XII	$8''$
XIII	$16''\frac{1}{4}$
XIV	$36''\frac{1}{4}$

Scale-Value Corrections, Projection Errors, and Deviation of the Cylinder from Straightness.—None of these have any appreciable effect. The first is due to the fact that the scale is made of German silver, while the plate is glass. Changes in temperature might, therefore, give rise to unequal expansion, and hence to a change in the scale-value. Dr. Schlesinger[1] in 1897 investigated this question, and his results show that in no case could this change affect my results by as much as $0''.04$. I have therefore felt justified in neglecting this error altogether.

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[1] See his "Præsepe" pp. 220–223.

The second category, projection errors, have been eliminated entirely in the case of the Repsold machine in use for the present research by an improved guiding way with which it was equipped in 1896.

As regards the deviation of the cylinder from straightness, an investigation made under Professor Jacoby's[1] direction shows that no appreciable error is introduced thereby, the greatest range of variation not exceeding 0″.04. I have therefore neglected this correction.

In Table V are recorded the final corrected coördinates obtained from the measures of Table III. The process of computing them is very simple: To the number of the line add the mean of the two corresponding ½*m*'s corrected for runs and division errors. In case two lines are used, substitute for the line of above the mean of the lines. The result is the mean position of the star with respect to the scale for each of the four positions of the plate. Then calculate the measured coördinates, as previously explained, by comparison of these four quantities with the corresponding quantities for the central star, obtained in the same manner. Apply thereto the rotation corrections, having care for the sign, and the result will be the quantities set down in Table V. No further explanation of the terms there used is necessary; it may be mentioned, however, that, as before, unity in the fourth place of decimals corresponds to about 0″.005.

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[1] "Permanence of the Rutherfurd Photographic Plates," Annals New York Academy of Sciences, Vol. IX, p. 207.

TABLE V: CORRECTED COÖRDINATES.—PLATE I.

Star.	x			y		
	Direct.	Rev'd.	Mean.	Direct.	Rev'd.	Mean.
4	—33.4486	.4522	—33.4504	+10.6314	.6347	+10.6330
5	—32.9343	.9338	—32.9340	+52.9854	.9858	+52.9856
6	—26.7422	.7442	—26.7432	— 5.3955	.3940	— 5.3948
7	—24.7756	.7789	—24.7772	+ 5.5318	.5353	+ 5.5336
8	—21.8240	.8270	—21.8255	— 8.4788	.4781	— 8.4784
9	—21.8558	.8547	—21.8552	—55.7458	.7367	—55.7412
10	—16.3928	.3916	—16.3922	—57.7500	.7487	—57.7494
14	0.0000	.0000	0.0000	0.0000	.0000	0.0000
15	+ 0.2751	.2735	+ 0.2743	— 1.2018	.1972	— 1.1995
21	+23.7752	.7740	+23.7746	+ 0.3586	.3601	+ 0.3594
22	+27.5780	.5766	+27.5773	+17.1978	.1985	+17.1982
23	+29.7712	.7702	+29.7707	—17.9134	.9107	—17.9120
24	+38.8579	.8559	+38.8569	—19.3756	.3737	—19.3746

PLATE II.

Star.	x			y		
	Direct.	Rev'd.	Mean.	Direct.	Rev'd.	Mean.
1	—58.2719	.2778	—58.2748	+23.5483	.5442	+23.5462
2	—53.0671	.0645	—53.0658	+11.2654	.2644	+11.2649
4	—33.4508	.4523	—33.4516	+10.6330	.6326	+10.6328
5	—32.9292	.9312	—32.9302	+52.9774	.9766	+52.9770
6	—26.7470	.7398	—26.7434	— 5.3878	.3947	— 5.3912
7	—24.7784	.7777	—24.7780	+ 5.5358	.5301	+ 5.5330
8	—21.8238	.8238	—21.8238	— 8.4796	.4852	— 8.4824
9	—21.8519	.8518	—21.8518	—55.7386	.7399	—55.7392
10	—16.3881	.3884	—16.3882	—57.7504	.7524	—57.7514
14	0.0000	.0000	0.0000	0.0000	.0000	0.0000
15	+ 0.2804	.2790	+ 0.2797	— 1.1986	.2021	— 1.2004
18	+ 9.7201	.7263	+ 9.7232	+ 0.3576	.3514	+ 0.3545
19	+15.1144	.1175	+15.1160	+48.9410	.9358	+48.9384
21	+23.7754	.7766	+23.7760	+ 0.3618	.3574	+ 0.3596
22	+27.5754	.5773	+27.5764	+17.2022	.1990	+17.2006
23	+29.7710	.7716	+29.7713	—17.9077	.9147	—17.9112
24	+38.8609	.8567	+38.8588	—19.3713	.3775	—19.3744

TABLE V. (*Continued.*)—PLATE III.

Star.	*x*			*y*		
	Direct.	Rev'd.	Mean.	Direct.	Rev'd.	Mean.
1	—58.2620	.2648	—58.2634	+25.5445	.5380	+23.5412
2	—53.0662	.0700	—53.0681	+11.2665	.2622	+11.2644
4	—33.4544	.4530	—33.4537	+10.6342	.6276	+10.6309
5	—32.9304	.9296	—32.9300	+52.9755	.9745	+52.9750
6	—26.7541	.7469	—26.7505	— 5.3911	.3963	— 5.3937
7	—24.7809	.7782	—24.7796	+ 5.5359	.5323	+ 5.5341
8	—21.8324	.8260	—21.8292	— 8.4786	.4822	— 8.4804
9	—21.8538	.8461	—21.8500	—55.7366	.7364	—55.7365
10	—16.3894	.3853	—16.3874	—57.7463	.7476	—57.7470
14	0.0000	.0000	0.0000	0.0000	.0000	0.0000
15	+ 0.2750	.2778	+ 0.2764	— 1.1972	.1977	— 1.1974
21	+23.7722	.7748	+23.7735	+ 0.3642	.3636	+ 0.3639
22	+27.5723	.5754	+27.5738	+17.2067	.2034	+17.2050
23	+29.7719	.7714	+29.7716	—17.9065	.9081	—17.9073
24	+38.8564	.8581	+38.8572	—19.3675	.3695	—19.3685

PLATE IV.

Star.	*x*			*y*		
	Direct.	Rev'd.	Mean.	Direct.	Rev'd.	Mean.
1	—58.2560	.2624	—58.2592	+23.5562	.5520	+23.5541
2	—53.0578	.0647	—53.0612	+11.2722	.2695	+11.2708
4	—33.4568	.4609	—33.4588	+10.6384	.6371	+10.6378
5	—32.9293	.9307	—32.9300	+52.9750	.9742	+52.9746
6	—26.7400	.7466	—26.7433	— 5.3934	.3934	— 5.3934
7	—24.7681	.7752	—24.7716	+ 5.5320	.5330	+ 5.5325
8	—21.8154	.8214	—21.8184	— 8.4838	.4825	— 8.4832
9	—21.8650	.8683	—21.8666	—55.7318	.7314	—55.7316
10	—16.3799	.3819	—16.3809	—57.7526	.7526	—57.7526
11	—11.6300	.6375	—11.6338	+51.8848	.8879	+51.8864
12	—10.4174	.4291	—10.4232	+47.8555	.8585	+47.8570
13	— 8.3504	.3548	— 8.3526	—10.9044	.9059	—10.9052
14	0.0000	.0000	0.0000	0.0000	.0000	0.0000
15	+ 0.2873	.2791	+ 0.2832	— 1.1969	.1957	— 1.1963
17	+ 2.8632	.8579	+ 2.8606	— 2.6923	.6944	— 2.6934
18	+ 9.7326	.7281	+ 9.7304	+ 0.3565	.3559	+ 0.3562
21	+23.7834	.7796	+23.7815	+ 0.3636	.3618	+ 0.3627
22	+27.5772	.5736	+27.5754	+17.2032	.2006	+17.2019
23	+29.7781	.7763	+29.7772	—17.9082	.9079	—17.9080
24	+38.8654	.8599	+38.8626	—19.3742	.3747	—19.3744

TABLE V. (*Continued.*)—PLATE V.

Star.	*x*			*y*		
	Direct.	Rev'd.	Mean.	Direct.	Rev'd.	Mean.
1	—58.2650	.2707	—58.2678	+23.5358	.5303	+23.5330
2	—53.0626	.0662	—53.0644	+11.2525	.2497	+11.2511
4	—33.4616	.4650	—33.4633	+10.6267	.6258	+10.6262
5	—32.9462	.9504	—32 9483	+52.9591	.9589	+52.9590
6	—26.7382	.7444	—26.7413	— 5.4030	.4030	— 5.4030
7	—24.7719	.7780	—24.7750	+ 5.5258	.5274	+ 5.5266
8	—21.8204	.8223	—21.8214	— 8.4910	.4940	— 8.4925
9	—21.8487	.8525	—21.8506	—55.7340	.7348	—55.7344
10	—16.3631	.3685	—16.3658	—57.7569	.7575	—57.7572
13	— 8.3530	.3578	— 8.3554	—10.9114	.9105	—10.9110
14	0.0000	.0000	0.0000	0.0000	.0000	0.0000
15	+ 0.2886	.2818	+ 0.2852	— 1.1988	.1988	— 1.1988
18	+ 9.7282	.7244	+ 9.7263	+ 0.3561	.3549	+ 0.3555
19	+15.1028	.0974	+15.1001	+48.9430	.9453	+48.9442
21	+23.7781	.7737	+23.7759	+ 0.3662	.3684	+ 0.3673
22	+27.5677	.5650	+27.5664	+17.2096	.2033	+17.2064
23	+29.7851	.7794	+29.7822	—17.8990	.8979	—17.8984
24	+38.8670	.8616	+38.8643	—19.3621	.3586	—19.3604

PLATE VI.

Star.	*x*			*y*		
	Direct.	Rev'd.	Mean.	Direct.	Rev'd.	Mean.
1	—58.2580	.2618	—58.2599	+23.5561	.5588	+23.5574
2	—53.0621	.0613	—53.0617	+11.2721	.2736	+11.2728
3	—50.0673	.0729	—50.0701	—53.2676	.2650	—53.2663
4	—33.4605	.4633	—33.4619	+10.6406	.6420	+10.6413
5	—32.9322	.9349	—32.9336	+52.9704	.9730	+52.9717
6	—26.7438	.7493	—26.7466	— 5.3929	.3892	— 5.3910
7	—24.7752	.7780	—24.7766	+ 5.5377	.5386	+ 5.5382
8	—21.8209	.8245	—21.8227	— 8.4811	.4792	— 8.4802
9	—21.8743	.8745	—21.8744	—55.7257	.7217	—55.7237
10	—16.3890	.3880	—16.3885	—57.7475	.7452	—57.7464
11	—11.6369	.6420	—11.6394	+51.8649	.8696	+51.8672
12	—10.4297	.4324	—10.4310	+47.8528	.8597	+47.8562
13	— 8.3571	.3636	— 8.3604	—10.9046	.9033	—10.9040
14	0.0000	.0000	0.0000	0.0000	.0000	0.0000
15	+ 0.2826	.2762	+ 0.2794	— 1.1996	.1968	— 1.1982
16	+ 1.1405	.1328	+ 1.1366	+52.7970	.8062	+52.8016
18	+ 9.7236	.7226	+ 9.7231	+ 0.3517	.3550	+ 0.3534
19	+15.1181	.1156	+15.1168	+48.9331	.9424	+48.9378
21	+23.7693	.7665	+23.7679	+ 0.3593	.3604	+ 0.3598
22	+27.5703	.5701	+27.5702	+17.2003	.1994	+17.1998
23	+29.7688	.7652	+29.7670	—17.9120	.9106	—17.9113
24	+38.8544	.8484	+38.8514	—19.3774	.3776	—19.3775

TABLE V. (*Continued.*)—PLATE VII.

Star.	x			y		
	Direct.	Rev'd.	Mean.	Direct.	Rev'd.	Mean.
1	—58.2601	.2651	—58.2626	+23.5588	.5526	+23.5557
2	—53.0655	.0687	—53.0671	+11.2748	.2747	+11.2748
4	—33.4650	.4662	—33.4656	+10.6410	.6428	+10.6419
5	—32.9299	.9332	—32.9316	+52.9760	.9726	+52.9743
6	—26.7556	.7570	—26.7563	— 5.3908	.3920	— 5.3914
7	—24.7795	.7817	—24.7806	+ 5.5342	.5370	+ 5.5356
8	—21.8218	.8267	—21.8242	— 8.4808	.4818	— 8.4813
9	—21.8783	.8788	—21.8786	—55.7250	.7232	—55.7241
10	—16.3971	.3976	—16.3974	—57.7537	.7519	—57.7528
14	0.0000	.0000	0.0000	0.0000	.0000	0.0000
15	+ 0.2794	.2742	+ 0.2768	— 1.2020	.2012	— 1.2016
18	+ 9.7144	.7113	+ 9.7128	+ 0.3494	.3496	+ 0.3495
21	+23.7738	.7674	+23.7706	+ 0.3568	.3545	+ 0.3556
22	+27.5792	.5780	+27.5786	+17.2016	.1974	+17.1995
23	+29.7699	.7658	+29.7678	—17.9171	.9181	—17.9176
24	+38.8525	.8476	+38.8500	—19.3797	.3778	—19.3788

PLATE VIII.

Star.	x			y		
	Direct.	Rev'd.	Mean.	Direct.	Rev'd.	Mean.
1	—58.2581	.2575	—58.2578	+23.5670	.5632	+23.5651
2	—53.0606	.0615	—53.0610	+11.2769	.2776	+11.2772
4	—33.4612	.4587	—33.4600	+10.6426	.6452	+10.6439
5	—32.9260	.9246	—32.9253	+52.9780	.9778	+52.9779
6	—26.7405	.7376	—26.7390	— 5.3864	.3878	— 5.3871
7	—24.7710	.7703	—24.7706	+ 5.5386	.5385	+ 5.5386
8	—21.8209	.8191	—21.8200	— 8.4806	.4798	— 8.4802
9	—21.8729	.8683	—21.8706	—55.7246	.7226	—55.7236
10	—16.3856	.3847	—16.3852	—57.7510	.7526	—57.7518
11	—11.6298	.6259	—11.6278	+51.8749	.8754	+51.8752
12	—10.4207	.4170	—10.4188	+47.8600	.8604	+47.8602
13	— 8.3557	.3530	— 8.3544	—10.9043	.9070	—10.9056
14	0.0000	.0000	0.0000	0.0000	.0000	0.0000
15	+ 0.2870	.2872	+ 0.2871	— 1.1968	.1988	— 1.1978
16	+ 1.1388	.1420	+ 1.1404	+52.8096	.8088	+52.8092
17	+ 2.8614	.8654	+ 2.8634	— 2.6900	.6924	— 2.6912
18	+ 9.7342	.7326	+ 9.7334	+ 0.3557	.3564	+ 0.3560
19	+15.1191	.1238	+15.1214	+48.9421	.9451	+48.9436
20	+18.1893	.1945	+18.1919	+51.4121	.4146	+51.4134
21	+23.7749	.7760	+23.7754	+ 0.3616	.3592	+ 0.3604
22	+27.5738	.5757	+27.5748	+17.1986	.1958	+17.1972
23	+29.7734	.7743	+29.7738	—17.9118	.9150	—17.9134
24	+38.8538	.8543	+38.8540	—19.3720	.3780	—19.3750

TABLE V. (*Continued.*)—PLATE IX.

Star.	*x*			*y*		
	Direct.	Rev'd.	Mean.	Direct.	Rev'd.	Mean.
1	—58.2551	.2582	—58.2566	+23.5698	.5634	+23.5666
2	—53.0613	.0698	—53.0656	+11.2819	.2823	+11.2821
4	—33.4606	.4641	—33.4624	+10.6450	.6460	+10.6455
5	—32.9182	.9217	—32.9200	+52.9774	.9768	+52.9771
7	—24.7786	.7778	—24 7782	+ 5.5375	.5343	+ 5.5359
8	—21.8298	.8329	—21.8314	— 8.4781	.4811	— 8.4796
9	—21.8934	.8956	—21.8945	—55.7175	.7174	—55.7174
10	—16.4058	.4102	—16.4080	—57.7476	.7446	—57.7461
14	0.0000	.0000	0.0000	0.0000	.0000	0.0000
15	+ 0.2803	.2794	+ 0.2798	— 1.2007	.2009	— 1.2008
21	+23.7728	.7681	+23.7704	+ 0.3512	.3523	+ 0.3518
22	+27.5804	.5754	+27.5779	+17.1920	.1910	+17.1915
23	+29.7660	.7615	+29.7638	—17.9179	.9176	—17.9178
24	+38.8439	.8396	+38.8418	—19.3814	.3847	—19.3830

PLATE X.

Star.	*x*			*y*		
	Direct.	Rev'd.	Mean.	Direct.	Rev'd.	Mean.
1	—58.2564	.2625	—58.2594	+23.5601	.5552	+23.5576
2	—53.0639	.0642	—53.0640	+11.2759	.2752	+11.2756
4	—33.4631	.4610	—33.4620	+10.6417	.6424	+10.6420
5	—32.9253	.9203	—32.9228	+52.9682	.9704	+52.9693
6	—26.7460	.7428	—26.7444	— 5.3868	.3884	— 5.3876
7	—24.7753	.7745	—24.7749	+ 5.5351	.5354	+ 5.5352
8	—21.8284	.8262	—21.8273	— 8.4829	.4840	— 8.4834
9	—21.8890	.8859	—21.8874	—55.7277	.7219	—55.7248
10	—16.3983	.3957	—16.3970	—57.7508	.7466	—57.7487
14	0.0000	.0000	0.0000	0.0000	.0000	0.0000
15	+ 0.2781	.2789	+ 0.2785	— 1.2034	.2018	— 1.2026
18	+ 9.7222	.7286	+ 9.7254	+ 0.3488	.3470	+ 0.3479
21	+23.7712	.7742	+23.7727	+ 0.3565	.3560	+ 0.3562
22	+27.5761	.5817	+27.5789	+17.1948	.1934	+17.1941
23	+29.7670	.7706	+29.7688	—17.9144	.9137	—17.9140
24	+38.8486	.8532	+38.8509	—19.3782	.3807	—19.3794

TABLE V. (*Continued.*)—PLATE XI.

Star.	*x*			*y*		
	Direct.	Rev'd.	Mean.	Direct.	Rev'd.	Mean.
1	−58.2564	.2592	−58.2578	+23.5596	.5562	+23.5579
2	−53.0621	.0660	−53.0640	+11.2741	.2711	+11.2726
4	−33.4594	.4597	−33.4596	+10.6401	.6392	+10.6396
5	−32.9226	.9234	−32.9230	+52.9687	.9684	+52.9686
6	−26.7522	.7479	−26.7500	− 5.3871	.3895	− 5.3883
7	−24.7722	.7697	−24.7710	+ 5.5390	.5372	+ 5.5381
8	−21.8256	.8179	−21.8218	− 8.4805	.4841	− 8.4823
9	−21.8870	.8816	−21.8843	−55.7231	.7197	−55.7214
10	−16.3952	.3924	−16.3938	−57.7490	.7449	−57.7470
14	0.0000	.0000	0.0000	0.0000	.0000	0.0000
15	+ 0.2768	.2814	+ 0.2791	− 1.1956	.1970	− 1.1963
18	+ 9.7216	.7226	+ 9.7221	+ 0.3549	.3513	+ 0.3531
21	+23.7726	.7726	+23.7726	+ 0.3580	.3544	+ 0.3562
22	+27.5747	.5749	+27.5748	+17.1969	.1944	+17.1956
23	+29.7672	.7668	+29.7670	−17.9136	.9128	−17.9132
24	+38.8473	.8506	+38.8490	−19.3756	.3799	−19.3778

PLATE XII.

Star.	*x*			*y*		
	Direct.	Rev'd.	Mean.	Direct.	Rev'd.	Mean.
1	−58.2619	.2679	−58.2649	+23.5591	.5483	+23.5537
2	−53.0571	.0612	−53.0592	+11.2716	.2644	+11.2680
4	−33.4623	.4624	−33.4624	+10.6422	.6340	+10.6381
5	−32.9350	.9345	−32.9348	+52.9690	.9676	+52.9683
6	−26.7476	.7440	−26.7458	− 5.3892	.3946	− 5.3919
7	−24.7767	.7716	−24.7742	+ 5.5382	.5334	+ 5.5358
8	−21.8276	.8221	−21.8248	− 8.4786	.4854	− 8.4820
9	−21.8805	.8760	−21.8782	−55.7190	.7243	−55.7216
10	−16.3883	.3869	−16.3876	−57.7489	.7512	−57.7500
14	0.0000	.0000	0.0000	0.0000	.0000	0.0000
15	+ 0.2779	.2774	+ 0.2776	− 1.1961	.2012	− 1.1986
18	+ 9.7161	.7202	+ 9.7182	+ 0.3594	.3524	+ 0.3559
21	+23.7740	.7724	+23.7732	+ 0.3644	.3568	+ 0.3606
22	+27.5728	.5718	+27.5723	+17.1999	.1943	+17.1971
23	+29.7736	.7704	+29.7720	−17.9049	.9146	−17.9098
24	+38.8513	.8524	+38.8518	−19.3698	.3767	−19.3732

TABLE V. (*Continued.*)—PLATE XIII.

Star.	*x*			*y*		
	Direct.	Rev'd.	Mean.	Direct.	Rev'd.	Mean.
1	—58.2619	.2583	—58.2601	+23.5697	.5633	+23.5665
2	—53.0649	.0642	—53.0646	+11.2839	.2777	+11.2808
4	—33.4649	.4610	—33.4630	+10.6485	.6441	+10.6463
5	—32.9213	.9176	—32.9194	+52.9749	.9731	+52.9740
6	—26.7510	.7398	—26.7454	— 5.3814	.3909	— 5.3862
7	—24.7777	.7690	—24.7734	+ 5.5398	.5313	+ 5.5356
8	—21.8344	.8285	—21.8314	— 8.4738	.4819	— 8.4778
9	—21.9001	.8930	—21.8966	—55.7162	.7137	—55.7150
10	—16.4105	.4004	—16.4054	—57.7415	.7444	—57.7430
14	0.0000	.0000	0.0000	0.0000	.0000	0.0000
15	+ 0.2760	.2802	+ 0.2781	— 1.1978	.2032	— 1.2005
21	+23.7697	.7720	+23.7708	+ 0.3552	.3505	+ 0.3528
22	+27.5772	.5806	+27.5789	+17.1957	.1904	+17.1930
23	+29.7630	.7638	+29.7634	—17.9165	.9203	—17.9184
24	+38.8422	.8490	+38.8456	—19.3818	.3866	—19.3842

PLATE XIV.

Star.	*x*			*y*		
	Direct.	Rev'd.	Mean.	Direct.	Rev'd.	Mean.
1	—58.2545	.2616	—58.2580	+23.5619	.5552	+23.5586
2	—53.0607	.0651	—53.0629	+11.2787	.2722	+11.2754
4	—33.4612	.4612	—33.4612	+10.6423	.6374	+10.6398
5	—32.9212	.9237	—32.9224	+52.9696	.9671	+52.9684
6	—26.7502	.7507	—26.7504	— 5.3838	.3923	— 5.3880
7	—24.7776	.7771	—24.7774	+ 5.5392	.5299	+ 5.5346
8	—21.8272	.8254	—21.8263	— 8.4792	.4873	— 8.4832
9	—21.8933	.8880	—21.8906	—55.7181	.7237	—55.7209
10	—16.4015	.3999	—16.4007	—57.7497	.7480	—57.7488
14	0.0000	.0000	0.0000	0.0000	.0000	0.0000
15	+ 0.2740	.2768	+ 0.2754	— 1.1978	.2043	— 1.2010
18	+ 9.7200	.7232	+ 9.7216	+ 0.3529	.3454	+ 0.3492
21	+23.7728	.7726	+23.7727	+ 0.3556	.3497	+ 0.3526
22	+27.5779	.5794	+27.5786	+17.1964	.1896	+17.1930
23	+29.7691	.7679	+29.7685	—17.9141	.9213	—17.9177
24	+38.8475	.8503	+38.8489	—19.3759	.3852	—19.3806

III. Method of Reduction.

Having obtained in the manner explained in the preceding section the measured coördinates of the stars on the plates, we are in position to deduce from them the differences in right ascension and in declination to which they correspond. It is plain that certain corrections must be applied before this can be accomplished. In the first place, a photograph is a plane picture of the sky; hence we must introduce the "Transformation Corrections." Then the stars' positions are affected by refraction, precession, nutation and aberration, and the measures must be freed therefrom. We shall find, however, in the progress of the work, that before we can apply these corrections to the measured coördinates, we must reduce the latter into differences of right ascension and of declination (except for the corrections mentioned above) by means of certain constants to be discussed later. These are found by comparing the positions with respect to a given origin of certain well known stars on the plates with their measured coördinates, corrected for refraction, etc. These constants being known, we shall find that by means of simple formulæ the measured coördinates can be transformed into angular distances and at the same time freed from the effects of refraction and errors of orientation. Adding these distances to the known coördinates of the origin of measures on the plate, we obtain the celestial coördinates of the stars except for the transformation corrections. The latter are then applied to the means of all the observations on each star, and we have the final right ascensions and declinations.

Let us proceed to discuss these several steps.

Transformation Corrections.—An astronomical photograph may be regarded as a central projection on a plane of part of the heavens. A certain quantity, known as the "Transformation Correction," must therefore be added to reduce any measured distance on the plate into the distance on the sky to which it corresponds. To find an expression for this correction, let us consider the spherical triangle whose vertices are the pole, the center of the plate, and any star on the plate. By center is meant the point at which a perpendicular on to its plane from the object glass cuts the plate. It is the point of tangency of the plate with the spherical image of the sky formed at the focus of the object glass. Now let

$\alpha_0 =$ the right ascension of the center, and
$\alpha =$ the right ascension of any star;
$p_0 =$ the north polar distance of the center, and
$p =$ that of the star;
$\eta =$ the parallactic angle at the center, and
$x =$ the angular distance from center to star;

then, by the usual formulæ [Chauvenet, Sph. Trig., Equ.'s (122), (123)]

$$\cos x = \frac{\cos(p_0 - q)\cos p}{\cos q} \tag{1}$$

$$\cot \eta = \frac{\sin(p_0 - q)\cot(\alpha - \alpha_0)}{\sin q} \tag{2}$$

where

$$\tan q = \tan p \cos(\alpha - \alpha_0). \tag{3}$$

Now consider a central projection of the figure onto a tangent plane at the center of the plate, O. Let OX, OY be the axes, OY being the projection of the hour circle through the center O, and OX being perpendicular to OY. Let also S be the projected position of the star, and X and Y its rectangular coördinates on the plate expressed in seconds of arc of a great circle, the positive directions being the same as those of the "Measured Coördinates" (cf. p. 427). Then we shall have, taking the radius of the sphere as unity,

$$\angle \eta = \angle\, YOS$$

$$X = OS \sin YOS$$

$$Y = OS \cos YOS.$$

Also

$$OS = \tan x,$$

so that

$$\left.\begin{aligned} X &= \tan x \sin \eta \\ Y &= \tan x \cos \eta \end{aligned}\right\} \qquad (4)$$

But from our spherical triangle

$$\sin x \sin \eta = \sin (a - a_0) \sin p. \qquad (5)$$

Dividing (5) by (1), and remembering (4) we get

$$\tan x \sin \eta = X = \frac{\sin (a - a_0) \sin p \cos q}{\cos (p_0 - q) \cos p}. \qquad (6)$$

Similarly multiplying (2) by (6) we get

$$\tan x \cos \eta = Y = \frac{\cos (a - a_0) \tan p \tan (p_0 - q)}{\tan q}. \qquad (7)$$

These expressions may be easily transformed by the aid of (3). We obtain finally

$$\left.\begin{aligned} X &= \frac{\tan (a - a_0) \sin q}{\cos (p_0 - q)} \\ Y &= \tan (p_0 - q) \\ \text{where} \quad \tan q &= \tan p \cos (a - a_0) \end{aligned}\right\} \qquad (8)^1$$

The formulæ (8) express rigorously the relation which holds between the true and the projected distances. They presuppose a knowledge of the scale-value, and of the position of the center, when the position of any other star may be found.

From these formulæ very convenient expressions can be obtained in the form of series, giving the transformation corrections to any desired degree of accuracy. They may be used with advantage to within 15° of the pole. Making the same assumptions as before with regard to the formulæ (8), let us write them:

$$X = \frac{\tan (a - a_0)}{\cos p_0 \cot q + \sin p_0} \qquad (9)$$

$$\cot q = \frac{Y \tan p_0 + 1}{\tan p_0 - Y}. \qquad (10)$$

---

[1] These are Turner's formulæ for transforming measured rectangular into celestial coördinates; cf. Observatory, Vol. 16, pp. 373 ff.

Substituting from (10) in (9) we get after slight reductions

$$X = \tan(\alpha - \alpha_0)\cos p_0\,[\tan p_0 - Y],$$

or since

$$\cos p_0 = \sin\delta_0, \quad \sin p_0 = \cos\delta_0,$$

$$\alpha - \alpha_0 = \Delta\alpha,$$

$$\tan\Delta\alpha = \frac{X}{\cos\delta_0 - Y\sin\delta_0} = \frac{X\sec\delta_0}{1 - Y\tan\delta_0}. \tag{11}$$

Apply to this last expression the formula

$$\tan^{-1} u = u - \tfrac{1}{3}u^3 + \tfrac{1}{5}u^5 - \ldots$$

and expand each term by division. To terms of the fourth order the resulting series will be

$$\left.\begin{array}{ll} \Delta\alpha = X\sec\delta_0 + A_1(X\sec\delta_0)Y & A_1 = \tan\delta_0, \\ \quad + A_2(X\sec\delta_0)Y^2 & A_2 = \tan^2\delta_0, \\ \quad + A_3(X\sec\delta_0)^3 & A_3 = -\tfrac{1}{3}, \\ \quad + A_4(X\sec\delta_0)^3 Y & A_4 = -\tan\delta_0, \\ \quad + A_5(X\sec\delta_0)Y^3 & A_5 = \tan^3\delta_0. \end{array}\right\} \tag{12}$$ [1]

The process may easily be continued to any number of terms; but for most cases even terms of the third order are almost inappreciable, and no accuracy is added by carrying the computations further. Higher terms will be necessary only when δ_0 becomes large, or when the plate covers more than 2° square.

Let us now seek to find a similar series for $\Delta\delta$. The method is entirely analogous to the preceding, but the algebraic work is much more intricate. For we cannot now eliminate δ and thus get rid of that quantity once for all. We must keep it in the reductions until the end, and then eliminate it by the relation

$$\delta = \delta_0 + \Delta\delta.$$

Let us consider again the expression for X in the form (9). Remembering the last of equations (8), we can transform this as follows: From (8) and (9)

$$X = \frac{\sin(\alpha - \alpha_0)\tan p}{\cos p_0 + \sin p_0 \tan p \cos(\alpha - \alpha_0)}. \tag{13}$$

From (8) and (10)

$$\tan p\cos(\alpha - \alpha_0) = \frac{\tan p_0 - Y}{Y\tan p_0 + 1}. \tag{14}$$

---

[1] See footnote, p. 443.

Hence, after slight reductions, from (13) and (14)

$$X = \sin(\alpha - \alpha_0)\tan p\,[Y \tan p_0 + 1]\cos p_0\,,$$

so that

$$\tan p = \frac{X}{\sin(\alpha - \alpha_0)\,[Y \sin p_0 + \cos p_0]}$$

or

$$\cot\delta = \frac{X}{\sin\Delta\alpha\,[Y\cos\delta_0 + \sin\delta_0]}$$

and

$$\tan(\delta_0 + \Delta\delta) = \frac{\sin\Delta\alpha\,[Y + \tan\delta_0]}{X\sec\delta_0}\,. \qquad (15)$$

Expanding and reducing we obtain finally :

$$\tan\Delta\delta = \frac{\sin\Delta\alpha\,[Y + \tan\delta_0] - X\sec\delta_0\tan\delta_0}{X\sec\delta_0 + \sin\Delta\alpha\,[Y + \tan\delta_0]\tan\delta_0}\,. \qquad (16)$$

This may be written, substituting for the sine,

$$\Delta\delta = \tan^{-1}\frac{\left(\Delta\alpha - \dfrac{\Delta\alpha^3}{6} + \dfrac{\Delta\alpha^5}{120}\right)[Y + \tan\delta_0] - X\sec\delta_0\tan\delta_0}{X\sec\delta_0 + \left(\Delta\alpha - \dfrac{\Delta\alpha^3}{6} + \dfrac{\Delta\alpha^5}{120}\right)[Y + \tan\delta_0]\tan\delta_0}\,,$$

and if we replace here $\Delta\alpha$ by its value from (12), divide the numerator by the denominator, and then apply the formula for expanding the arc-tan., we get, to terms of the fourth order, the following series for $\Delta\delta$:

$$\left.\begin{array}{ll} \Delta\delta = Y + D_1(X\sec\delta_0)^2 & D_1 = -\tfrac{1}{4}\sin 2\,\delta_0, \\ \qquad + D_2(X\sec\delta_0)^2 Y & D_2 = -\tfrac{1}{2}, \\ \qquad + D_3 Y^3 & D_3 = -\tfrac{1}{3}, \\ \qquad + D_4(X\sec\delta_0)^2 Y^2 & D_4 = -\tfrac{1}{2}\sin^2\delta_0\tan\delta_0, \\ \qquad + D_5(X\sec\delta_0)^4 & D_5 = \tfrac{1}{8}\,(3\sin\delta_0\cos^3\delta_0 \\ & \qquad + \sin^3\delta_0\cos\delta_0)\,. \end{array}\right\} \qquad (17)\text{[1]}$$

When $\Delta\alpha$ and $\Delta\delta$ are known approximately from meridian observations a still more convenient form may be deduced from (12) and (17) by inversion of series. It is preferable in several ways : the labor involved in the calculations is slightly smaller and the results are somewhat more accurate, as the $\Delta\alpha$ and $\Delta\delta$ used are free from errors of scale-value and orientation, which is not the case with the measured X and Y. The formulæ, arranged for calculation to terms of the third order, are as follows :

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[1] See footnote, p. 443.

$$\begin{aligned} \Delta\alpha - X \sec\delta_0 &= + \Delta\alpha\Delta\delta \cdot \tan\delta_0 \sin 1'' \\ &\quad - \Delta\alpha^3 \cdot \tfrac{1}{3}\left(1 - \tfrac{3}{2}\sin^2\delta_0\right)\sin^2 1''; \end{aligned} \tag*{(18)[1]}$$

$$\begin{aligned} \Delta\delta - Y &= - \Delta\alpha^2 \cdot \tfrac{1}{4}\sin 2\delta_0 \sin 1'' \\ &\quad - \Delta\alpha^2\Delta\delta \cdot \tfrac{1}{2}\cos 2\delta_0 \sin^2 1'' \\ &\quad - \Delta\delta^3 \cdot \tfrac{1}{3}\sin^2 1''. \end{aligned} \tag*{(19)[1]}$$

The simplicity and elegance of the above expressions are at once evident when we remember that δ_0 is the declination of the center of the plate, and is therefore constant for any group, or, in fact, for an entire zone. It is, however, necessary, that the position of the center should be known. As has previously been mentioned, Rutherfurd was careful to have this point coincide with some bright star; in the case of the Coma Plates the star selected was 12 *e* (my no. 14). Taking thus the values of $\Delta\alpha$ and $\Delta\delta$ from the *Catalog der Astronomischen Gesellschaft* (cf. the "LIST OF CATALOGUES" in Part I of the present paper), and applying formulæ (18) and (19) to each star, the quantities $(\Delta\alpha - X)\sec\delta_0$ and $\Delta\delta - Y$ are obtained. I have collected them in TABLE VI. Since the rectangular coördinates, x and y, were measured from the same star as origin, it is evident that the table will give at once the corrections which have to be added to $X \sec\delta_0$ and Y, *i. e.*, to the measured coördinates multiplied by the scale-value for the center of the plate, in order to change them to $\Delta\alpha$ and $\Delta\delta$. It is also plain that the table will be constant for all the plates, and that the corrections may therefore be applied equally well to the mean of all the determinations, as to each one separately. This I have done.

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[1] NOTE.—Equ.'s (12), (17), (18) and (19) were first deduced by this method by Professor Jacoby. See his review of "Donner, Determination des Constants, etc.," in the Vierteljahrsschrift for 1895, p. 114, where these series, to terms of the fifth order are given, but without demonstration. Previously, Ball and Rambaut in Trans. Roy. Irish Acad., XXX, P't. IV, had deduced the first two of the above expansions to terms of the third order, but they were obtained by a process entirely different from that shown here.

A few words more on this subject may not be amiss. In the first paragraph of this section it is stated that the transformation correction is applied in order to change a measured distance on the plate into the corresponding actual distance on the sky. That is, however, not all: it does something more than that, when the formulæ (12), (17) or (18), (19) are used. For they presuppose that all the measured y's are multiplied by p, and all the measured x's by $p \sec \delta_0$, where p is the equatorial scale-value, and δ_0 is the declination of the center of the plate. But by this process an error is introduced, as all the distances in right ascension whose declination is greater than δ_0 become too small, and *vice versa*. The great advantage in using the formulæ mentioned, is, that they take account of this fact, and permit a constant scale-value to be used for all the stars. They include still another correction, namely that due to the curvature of the projections on the plate of the parallels of declination, which are not straight lines, but arcs tangent to the direction of the axis of X, at their intersection with the axis of Y. These considerations will explain why the quantities in the table are not symmetrical with respect to the center.

TABLE VI.—TRANSFORMATION CORRECTIONS.

Star.	$\Delta\alpha - X \sec \delta_0$	$\Delta\delta - Y$	Star.	$\Delta\alpha - X \sec \delta_0$	$\Delta\delta - Y$
1	—10″.109	—11″.686	13	+0″.688	—0″.233
2	— 4.301	— 9.603	14	.000	.000
3	+20.249	— 8.028	15	—0.003	.000
4	— 2.645	— 3.825	16	+0.471	—0.176
5	—13.245	— 3.972	17	—0.059	—0.029
6	+ 1.119	— 2.412	18	+0.026	—0.321
7	— 1.015	— 2.084	19	+5.644	—0.938
8	+ 1.413	— 1.599	20	+7.140	—1.323
9	+ 9.188	— 1.366	21	+0.046	—1.916
10	+ 7.124	— 0.655	22	+3.567	—2.610
11	— 4.585	— 0.633	23	—4.065	—2.958
12	— 3.785	— 0.503	24	—5.781	—5.046

Refraction Corrections.—Much has been written on the subject of photographic refraction, and several formulæ published designed to eliminate its effect from the measured rectangular coördinates. I have used those of Professor Jacoby[1] which were deduced by him from Dr. Rambaut's formulæ published in the *Astronomische Nachrichten*, No. 3125. Let

φ = the latitude of the place, + 40° 43′ 50″ in my case;

$\theta - \alpha_0$ = the hour angle of the center of the plate, θ being the "Sidereal Time" from TABLE I, and α_0 the right ascension of star 14, roughly corrected to the date of observation;

δ_0 = the declination of the center, Star 14;

β = the constant of refraction computed for the center with the argument "True Zenith Distance," ζ_0, and multiplied by $\frac{66}{65}$ to allow for the increased refrangibility of the actinic rays[2]; so that $\beta = k' . \frac{66}{65}$ (Chauvenet, Astr., Vol. I, §§ 119, 120).

Now compute the quantities

$$\tan N = \cos(\theta - \alpha_0) \cot \phi$$

$$G = \cot(\delta_0 + N)$$

$$H = \tan(\theta - \alpha_0) \sin N \operatorname{cosec}(\delta_0 + N)$$

then will

$$\tan^2 \zeta_0 = G^2 + H^2 \qquad \text{(Chauvenet, Vol. I, equ. (20))}$$

$$M_x = \beta(1 + H^2) \sin 1''$$

$$N_x = \beta(G - \tan \delta_0) H \sec \delta_0 \sin 1''$$

$$M_y = \beta(G + \tan \delta_0) H \cos \delta_0 \sin 1''$$

$$N_y = \beta(1 + G^2) \sin 1''$$

and the refraction corrections will be

$$\text{Correction to } X \sec \delta_0 = M_x \cdot X \sec \delta_0 + N_x \cdot Y$$

$$\text{Correction to } Y = M_y \cdot X \sec \delta_0 + N_y \cdot Y$$

where evidently the coefficients of $X \sec \delta_0$ and Y in the second members are constant for each plate but vary for different plates.

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[1] Astronomical Journal, No. 387.

[2] Cf. Scheiner and Rambaut, Astrom. Nachrichten, No. 3255.

A very simple way of verifying the above formulæ is the following[1]: Bessel[2] gives corrections for clearing apparent differences in right ascension and declination, obtained by micrometric observations, from the effects of refraction in the form:

$$\Delta(\alpha' - \alpha) = s\kappa\,[\tan^2\zeta_0 \cos(p - q)\sin q$$
$$- \tan\zeta_0 \sin q \tan\delta_0 \cos p + \sin p]\sec\delta_0$$
$$\Delta(\delta' - \delta) = s\kappa\,[\tan^2\zeta_0 \cos(p - q)\cos q$$
$$+ \tan\zeta_0 \sin q \tan\delta_0 \sin p + \cos p]$$

where s and p are the measured distance and position angle, ζ_0 and q are the true zenith distance and parallactic angle at the middle point between the two stars, whose coördinates are (α, δ) and (α', δ'), and δ_0 is the declination of that point. Now (Chauvenet, Astronomy, Vol. II, p. 453)

$$\kappa \tan^2\zeta_0 = b - a$$

where, r being the refraction,

$$a = \frac{\sin\zeta_0}{\sin(\zeta_0 - r)} = \frac{1}{1 - r\cot\zeta_0} = \frac{1}{1 - k'}$$

$$b = \frac{d\zeta_0}{d\zeta_0 - dr} = \frac{1}{1 - \frac{dr}{d\zeta_0}} = \frac{1}{1 - k'\sec^2\zeta_0 - \frac{dk'}{d\zeta_0}\tan\zeta_0},$$

placing $\cos r = 1$, $\sin r = r$ and remembering that $r = k'\tan\zeta_0$ (Chauvenet, Vol. I, p. 171), where r and k' are expressed in parts of the radius. Expanding the expressions for a and b by division, we easily obtain

$$b - a = \kappa\tan^2\zeta_0 = k'\tan^2\zeta_0 + \frac{dk'}{d\zeta_0}\tan\zeta_0 + \cdots,$$

the succeeding terms being higher powers in k' and $\frac{dk'}{d\zeta_0}$ which can be neglected. For zenith distances less than 70° the term in $\frac{dk'}{d\zeta_0}$ may also be neglected. For inside that limit we have

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[1] Cf. Schlesinger's "Præsepe;" Note, p. 285, where the above method was first pointed out

[2] Astronomische Untersuchungen, Vol. I, p. 166; or Chauvenet, Astronomy, Vol. II, p. 458.

$$\frac{dk'}{d\zeta_0} = \beta^{A'}\ \gamma^{\lambda'}\ \frac{d\alpha'}{d\zeta_0} \quad \text{(Cf. Chauvenet, Vol. I, p. 171)}$$

with sufficient accuracy, as both A' and λ' are practically constant, and β and γ do not vary with the zenith distance. But this is only 0.00002 at the limit selected; and since the tangent of 70° is 2.7, the term $\frac{dk'}{d\zeta_0}$ tan ζ_0 will be inappreciable when ζ_0 is less than 70°. Hence we can write

$$\kappa \tan^2 \zeta_0 = k' \tan^2 \zeta_0$$

or

$$\kappa = k'$$

with sufficient accuracy for photographic work, where s is not large.

Let us then substitute in the original formulæ for $\Delta(\alpha' - \alpha)$ and $\Delta(\delta' - \delta)$ from the following equations :

$$\kappa = k'$$
$$s \sin p = X$$
$$s \cos p = Y$$
$$\tan \zeta_0 \sin q = H$$
$$\tan \zeta_0 \cos q = G$$

and they become

$$\Delta(\alpha' - \alpha) = k' X \sec \delta_0 (1 + H^2) + k' Y (G - \tan \delta_0) H \sec \delta_0$$
$$\Delta(\delta' - \delta) = k' X (G + \tan \delta_0) H + k' Y (1 + G^2)$$

where k' is expressed in parts of the radius. These formulæ are evidently identical with Professor Jacoby's except for the factor 66/65 by which k' must be multiplied in order to obtain β. It should be observed that in the above equations terms in the second and higher powers of s are neglected; for we take account neither of transformation corrections, nor of the fact that in Bessel's original formulæ the quantities ζ_0 and δ_0 are intended to apply to the middle point between the two stars, whereas we transfer them to the end of the arc. This is, however, entirely legitimate for most photographic plates.

I subjoin TABLE VII which shows the values of the four factors M_x, N_x, M_y, N_y for all of my plates.

Table VII.—Refraction Coefficients.

Plate.	M_x	N_x	M_y	N_y
I	+0.000307	—0.000017	+0.000048	+0.000313
II	.000331	.000022	.000078	.000319
III	.000287	.000001	.000003	.000306
IV	.000339	.000023	.000091	.000317
V	.000375	.000021	.000126	.000327
VI	.000424	.000011	.000168	.000342
VII	.000362	.000021	.000119	.000319
VIII	.000409	.000013	.000159	.000334
IX	.000303	.000017	.000049	.000308
X	.000320	.000021	.000072	.000312
XI	.000347	.000023	.000100	.000319
XII	.000384	.000019	.000134	.000329
XIII	.000294	.000015	.000044	.000302
XIV	.000312	.000021	.000068	.000306

Precession, Nutation, and Aberration.—None of these need be taken into account. For as regards the first two, they, being due to motions of the earth, cannot affect the configuration of the stars, although they shift the axes of reference. The absolute distances between the stars will, therefore, be unaffected by these causes, but the differences in right ascension and declination will be changed. If, then, we compute the constants by the method to be detailed later, *i, e.*, by comparing certain stars on the plate with their positions as obtained from meridian observations reduced to some convenient epoch, then it is evident that the resulting right ascensions and declinations from the plate will be referred to the same epoch, without the need of applying any corrections for precession or nutation. For the changes due to these causes consist partly in a motion of translation, and partly in a motion of rotation of the axes ; the former will be entirely eliminated, while the latter will be included in the orientation correction.

Aberration may also be neglected. For Bessel[1] has shown that it changes the position angles about a point equally, while it affects all the distances, in whatever direction, by a constant factor only. Its whole effect will therefore be included in the scale-value and orientation corrections, when these are obtained by the method now to be described.

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[1] Astronomische Untersuchungen, Vol. I, p. 207 ; or Chauvenet, Astronomy, Vol. II, p. 466.

Constants of the Plates.—Four quantities must be known for each plate, in order that we may determine the absolute positions of the stars whose coördinates have been measured. They are: the right ascension α_0 and the declination δ_0 of the center, or origin; the value in seconds of arc of one division of the scale; and the angle made by the axes to which the measurements are referred, with the axes of reference in the celestial sphere. To obtain them, we must compare the measured coördinates of certain stars ("standards") with the corresponding distances of the same stars, from the same point as origin, obtained from meridian observations. Matters will be greatly facilitated by a knowledge of approximate values for these constants. As regards my plates, such information was available. The position of the center which coincides with star 14 (12*e* Comæ), was accurately known; the approximate scale-value was placed at

$$1 \text{ mm.} = 52''.87,$$

that being the result of a previous reduction of Rutherfurd's photographs of the Pleiades; while the orientation correction, due to the rotation of the axes, would be necessarily small, owing to the manner in which the plate was adjusted in the measuring machine.

We must now obtain the distances $\Delta\alpha = \alpha - \alpha_0$, and $\Delta\delta = \delta - \delta_0$, for certain stars on the plates. Let us return to Part I, Section III of this paper. We find there (p. 396) a catalogue of twelve stars suitable for this purpose. Of these, the following eleven are sufficiently well observed to serve as "standards": 2, 3, 5, 6, 10, 11, d, 14, 18, 19, 20. These are Chase's numbers; they correspond to my numbers 1, 2, 4, 5, 9, 10, 14, 15, 21, 22, 23, respectively. In the following I shall designate them by the latter numbers only. But before proceeding to obtain $\Delta\alpha$ and $\Delta\delta$ for these stars, we must apply a correction for proper motion.

For, the photographs being taken at three different dates, namely 1870.3 (Plates I–III), 1875.4 (Plates IV–VIII), and 1876.4 (Plates IX–XIV), the relative positions of the standards will not be the same for them all, due to the cause mentioned. As the epoch of reduction is to be 1875, we must not apply any correction for precession or nutation, otherwise what has been said above regarding this matter would not apply. We can, then, construct TABLE VIII. This table gives the Right Ascensions and Proper Motions in Right Ascension, and the Declinations and Proper Motions in Declination, for 1875. Then follow six columns showing the seconds of the Right Ascensions and Declinations with the proper motions applied to reduce them to the three dates mentioned; and in the last two columns will be found the Weights in Right Ascension and in Declination, respectively, of each star for 1870 and 1875. The same weights were used for 1875 and 1876. They were calculated by reversing the process for obtaining the probable errors explained in Part I, Sect. II, "FORMULÆ FOR ADJUSTMENT." From these quantities we can then obtain $\Delta\alpha$ and $\Delta\delta$ with their weights for each "standard" on every plate.

Now let us compute for each standard on each plate the quantities n_x and n_y as follows: From TABLE V we obtain x and y for each star. Form the products $X \sec \delta_0 = x \sec \delta_0 \,.\, 52''.87$ and $Y = y \,.\, 52''.87$. Correct these for refraction by means of TABLE VII and the corresponding formulæ, and apply the transformation corrections from TABLE VI. Subtract from the sums thus obtained the corresponding $\Delta\alpha$ or $\Delta\delta$: the differences will be $n_x \sec \delta_0$ and n_y. It is then evident that n_x and n_y should be zero, if it were not for errors of observation, and for errors in the assumed constants. We are to find the values of the latter. Let us introduce the notation:

$p =$ the correction to the assumed scale-value, so that the true value is $52''.87\ (1 + p)$;

$r =$ the orientation correction, or small angle through which the axes must be rotated in the direction of decreasing position angles;

TABLE VIII.—COÖRDINATES OF THE STANDARDS.

No.	At 1875.				At 1870.3.		At 1875.4.		At 1876.4.		1870.		1875.	
	Right Asc.	μ.	Declination.	μ′.	Sec. of α.	Sec. of δ.	Sec. of α.	Sec. of δ.	Sec. of α.	Sec. of δ.	Wt. α.	Wt. δ.	Wt α.	Wt. δ.
1	183° 5′ 43″.50	—0″.039	26° 52′ 58″.24	+0″.086	43″.68	57″.84	43″.48	58″.27	43″.45	58″.36	4.0	4.0	4.2	4.2
2	10 55.96	—0.074	26 42 10.65	—0.009	56.31	10.69	55.93	10.65	55.86	10.64	5.6	6.3	4.9	5.4
4	30 16.70	—0.210	26 41 42.94	+0.030	17.69	42.80	16.62	42.95	16.41	42.98	5.6	6.4	4.9	5.5
5	30 37.80	—0.106	27 19 2.26	—0.106	38.30	2.76	37.76	2.22	37.65	2.11	7.6	12.0	5.7	8.7
9	41 53.76	—0.249	25 43 14.48	+0.144	54.93	13.80	53.66	14.54	53.41	14.68	3.5	4.3	2.9	3.8
10	47 16.77	—0.048	25 41 28.01	+0.004	17.00	27.99	16 75	28.01	16.70	28.02	2.9	3.1	2.3	2.3
14	184 3 18.03	—0.033	26 32 23.98	+0.007	18.19	23.95	18.02	23.98	17.98	23.99	27.8	32.3	23.5	28.9
15	3 34.40	+0.006	26 31 20.26	+0.088	34.37	19.85	34.40	20.30	34.41	20.38	1.9	2.6	4.2	3.7
21	26 44.18	—0.030	26 32 40.72	+0.015	44.32	40.65	44.17	40.73	44.14	40.74	8.9	9.7	7.5	8.4
22	30 32.58	—0.038	26 47 31.03	—0.004	32.76	31.05	32.56	31.03	32.53	31.02	16.5	16.8	13.8	14.1
23	32 33.99	—0.048	26 16 33.15	+0.016	34.22	33.07	33.97	33.16	33.92	33.17	10.9	10.6	8.8	8.6

k = the correction in seconds of arc of a great circle to be added to the assumed right ascension of the center ;

c = the correction in seconds of arc of a great circle to be added to the assumed declination of the center.

Then the measured coördinates in seconds of arc of a great circle, X and Y, will require the following corrections :

Due to erroneous scale-value,

$$\text{Correction to } X = +pX$$
$$\text{Correction to } Y = +pY;$$

Due to orientation error, remembering that r is small,

$$\text{Correction to } X = +rY$$
$$\text{Correction to } Y = -rX;$$

Due to errors in the assumed position of the center,

$$\text{Correction to } X = +k$$
$$\text{Correction to } Y = +c.$$

It is evident that if we add the sum of these corrections to X and Y corrected for refraction and for transformation errors, we should obtain $\Delta\alpha \cos \delta_0$ and $\Delta\delta$ respectively. We have, therefore, from each star, two equations of the form

$$k + pX + rY + n_x = v_1$$
$$c + pY - rX + n_y = v_2$$

where the v's, as usual, are the residual errors due to inaccuracy of the observations.

Let us now form, for each plate, equations like the above for every standard measured ; we shall get a set of observation equations, from which the constants can be determined by the method of least squares. Usually, when all the n's have the same weight, or when the weights of corresponding equations in the two coördinates are equal, it is possible to abridge the labor considerably by means of certain formulæ deduced by Professor Jacoby.[1] As given by him, they apply to the case of equal weights only, but they might easily be generalized. I could not make use of this method, however. For, owing to the manner in which n_x and n_y were obtained (namely, by using $\Delta\alpha$ and $\Delta\delta$ obtained from catalogue positions), their weights are quite irregular. The formulæ of the general theory, therefore, had to be used. Each equation was first multiplied by the square root of the weight of the star on which the absolute term depended. This, although not theoretically correct (since the weight should take account of the uncertainty in the position of the central star, and also of that of the measured photographic coördinates), was found to be sufficiently accurate, owing to the minuteness of the unknowns. For the same reason, no appreciable error was committed by dividing the coefficients X and Y by 100, and retaining only the first place of decimals, while the arithmetical work was greatly simplified thereby. The following set of observation equations was thus obtained:

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[1] Monthly Notices, May, 1896, p. 424.

$$\begin{array}{c}
\sqrt{p_1}\,k + \sqrt{p_1}\,Xp' + \sqrt{p_1}\,Yr' + \sqrt{p_1}\,n_x = 0 \\
\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \\
\sqrt{p_n}\,c + \sqrt{p_n}\,Yp' - \sqrt{p_n}\,Xr' + \sqrt{p_n}\,n_y = 0 \\
\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots
\end{array}$$

where $\sqrt{p_i}$ is the square root of the weight, $(n - 1)$ is the number of standards used, $p' = 100p$, p being the scale-value desired, and $r' = 100\,r$. To find the unknowns, the following method was used, a demonstration of which is given in Jordan, *Handbuch der Vermessungskunde*, Vol. I, p. 97 (4th edit.). Form the two sets of normals:

$$\begin{array}{rrrrl}
[p_1]k + [p_1X_1]p' & + [p_1Y_1]r' & + [p_1n_x] & = 0 \\
{}[p_1X_1X_1]p' & + [p_1X_1Y_1]r' & + [p_1X_1n_x] & = 0 \\
& [p_1Y_1Y_1]r' & + [p_1Y_1n_x] & = 0 \\
[p_2]c + [p_2Y_2]p' & - [p_2X_2]r' & + [p_2n_y] & = 0 \\
{}[p_2Y_2Y_2]p' & - [p_2X_2Y_2]r' & + [p_2Y_2n_y] & = 0 \\
& [p_2X_2X_2]r' & - [p_2X_2n_y] & = 0
\end{array}$$

where the subscripts $_1$ refer to the equations, containing k, and the subscripts $_2$ to those containing c. Now eliminate k and c as usual, obtaining

$$k = -\frac{[p_1 X_1]}{[p_1]} p' - \frac{[p_1 Y_1]}{[p_1]} r' - \frac{[p_1 n_x]}{[p_1]}$$

$$c = -\frac{[p_2 Y_2]}{[p_2]} p' + \frac{[p_2 X_2]}{[p_2]} r' - \frac{[p_2 n_y]}{[p_2]},$$

and

$$\begin{aligned} [p_1 X_1 X_1 \cdot 1] p' + [p_1 X_1 Y_1 \cdot 1] r' + [p_1 X_1 n_x \cdot 1] &= 0 \\ [p_1 Y_1 Y_1 \cdot 1] r' + [p_1 Y_1 n_x \cdot 1] &= 0 \end{aligned}$$

$$\begin{aligned} [p_2 Y_2 Y_2 \cdot 1] p' + [p_2 X_2 Y_2 \cdot 1] r' + [p_2 Y_2 n_y \cdot 1] &= 0 \\ [p_2 X_2 X_2 \cdot 1] r' + [p_2 X_2 n_y \cdot 1] &= 0 \end{aligned}$$

Add the first and third, and the second and fourth of the last equations, term to term, and from the resulting equations obtain p' and r'. The values will be identically the same as if all the four unknowns had been eliminated from one set of normals by the general method.

The weights of the unknowns could, in this case, at once be written down, with sufficient accuracy. For owing to the fact that the weights in right ascension and in declination of the observation equations are nearly equal, we have

$$[p_1 X_1 X_1 \cdot 1] + [p_2 Y_2 Y_2 \cdot 1] = [p_1 Y_1 Y_1 \cdot 1] + [p_2 X_2 X_2 \cdot 1]$$

nearly and

$$[p_1 X_1 Y_1 \cdot 1] + [p_2 X_2 Y_2 \cdot 1]$$

small, so that we can place (cf. Chauvenet, Astronomy, Vol. II, p. 537)

$$\text{Wt of } p' = [p_1 X_1 X_1 \cdot 1] + [p_2 Y_2 Y_2 \cdot 1]$$

$$\text{Wt. of } r' = [pYY \cdot 3]$$

where $[pYY \cdot 3]$ denotes the coefficient of r' in the last elimination equation. Similarly, in the inverted elimination, the coefficients of p' and r' are very large compared to those of k and c, so that at once

$$\text{Wt. } k = [p_1] \text{ of the equations containing } k$$

$$\text{Wt. } c = [p_2] \text{ of the equations containing } c.$$

Knowing the weights, the probable errors were then obtained in the usual manner from the residuals.

It now remains only to make use of the constants obtained by the methods described above. This is a simple matter. For we have to apply to the measured coördinates the corrections

$$\begin{array}{llll} +p\cdot X\sec\delta_0 & +r\sec\delta_0\cdot\ Y & +k\sec\delta_0 & \text{to } X\sec\delta_0 \\ +p\cdot Y & -r\cdot X & +c & \text{to } Y \end{array}$$

due to errors in the assumed constants, and

$$\begin{array}{ll} +M_x\cdot X\sec\delta_0+N_xY & \text{to } X\sec\delta_0 \\ +M_y\cdot X\sec\delta_0+N_yY & \text{to } Y \end{array}$$

due to refraction. If then we add $X\sec\delta_0$ and Y, corrected by the process explained above to α_0 and δ_0 respectively, where α_0 and δ_0 are the assumed coördinates of the center, we will obtain for each star certain quantities, α_1 and δ_1, which are defined by the equations

$$\alpha=\alpha_1+T_\alpha$$
$$\delta=\delta_1+T_\delta$$

where α and δ are the right ascension and the declination respectively of the given star, and T_α and T_δ are the corresponding transformation corrections. α_1 and δ_1 may be called the "projected" coördinates of the star. Collecting all these operations together, it is evident that we can write the following formulæ:

$$\begin{array}{ll} \alpha_1=(1+p+M_x)X\sec\delta_0+(N_x+r\sec\delta_0)\,Y & +(\alpha_0+k\sec\delta_0) \\ \delta_1=(1+p+N_y)\,Y\qquad+(M_y-r\cos\delta_0)X\sec\delta_0 & +(\delta_0+c), \end{array}$$

and

$$\alpha=\alpha_1+T_\alpha,\quad \delta=\delta_1+T_\delta$$

and when taken in connection with the preceding discussion, it is evident that these equations express in mathematical language all the steps necessary to transform the measured rectangular coördinates on the plates, x and y, into the corresponding right ascensions and declinations on the celestial sphere.

IV. Results.

Constants.—Making the least square solution for each plate as explained Sect. III, we get the constants set down in Table IX. They all depend on eleven standards, except in the case of Plate I, where two of these are missing, owing to inaccurate pointing of the telescope. The probable errors computed for *p* and *r* in no case differed by more than a unit in the last place; I have therefore given only one value, which applies to both these quantities.

Table IX.—Constants.

Plate.	*p*	*r*	Probable Error of *p* or *r*.	*k*	Prob. Error of *k*.	*c*	Prob. Error of *c*.
				″	″	″	″
I	+0.000240	+0.000117	±0.000030	+0.135	±0.056	—0.119	±0.053
II	+ 238	+ 205	± 28	+0.131	±0.058	—0.083	±0.054
III	+ 308	+ 192	± 26	+0.148	±0.052	—0.174	±0.048
IV	+ 233	+ 194	± 26	—0.073	±0.050	—0.178	±0.047
V	+ 265	+ 540	± 28	+0.003	±0.056	—0.100	±0.052
VI	+ 260	+ 187	± 26	+0.166	±0.052	—0.161	±0.049
VII	+ 210	+ 92	± 24	+0.139	±0.046	—0.084	±0.044
VIII	+ 215	+ 118	± 27	—0.018	±0.053	—0.176	±0.050
IX	+ 290	— 140	± 24	+0.160	±0.048	—0.095	±0.045
X	+ 283	+ 11	± 24	+0.069	±0.048	—0.060	±0.045
XI	+ 307	+ 60	± 25	+0.089	±0.049	—0.089	±0.046
XII	+ 266	+ 199	± 29	+0.093	±0.057	—0.108	±0.053
XIII	+ 307	— 132	± 24	+0.161	±0.048	—0.107	±0.045
XIV	+ 304	— 25	± 24	+0.093	±0.048	—0.017	±0.045

It will be seen that the probable errors agree very well, so that the final positions from all the plates are entitled to an equal amount of confidence. A probable error in *p* or *r* of ± 0.000025 corresponds to an uncertainty of about 0″.08 of arc of a great circle in the position of the most outlying star. The great diversity in the values of *r* is due for the most part to the accidental position in which the plate was set in the measuring machine.

The following are the residuals obtained by introducing the values of the constants given above in the respective observation equations (p. 452):

From the Right Ascensions:

Plate.	Star 1.	Star 2.	Star 4.	Star 5.	Star 9.	Star 10.	Star 14.	Star 15.	Star 21.	Star 22.	Star 23.
I			+0″.14	—0″.25	—0″.03	—1″.03	+0″.14	+0″.16	—0″.12	—0″.10	+0″.26
II	—1″.02	0″.00	+0.08	+0.15	—0.12	—1.09	+0.13	+0.44	—0.04	—0.05	+0.24
III	—0.39	—0.17	—0.06	+0.15	—0.05	—1.08	+0.15	+0.28	—0.11	—0.12	+0.31
IV	—0.32	+0.19	+0.28	+0.25	—0.10	—0.81	—0.07	+0.24	+0.04	—0.28	+0.43
V	—0.48	+0.12	+0.20	+0.21	—0.28	—1.05	.00	+0.40	—0.08	—0.26	+0.55
VI	—0.46	+0.10	+0.16	+0.11	—0.41	—1.08	+0.17	+0.29	—0.30	—0.15	+0.31
VII	—0.42	+0.06	+0.08	+0.10	—0.22	—1.16	+0.14	+0.12	—0.32	+0.02	+0.25
VIII	—0.44	+0.09	+0.15	+0.28	—0.12	—0.82	—0.02	+0.51	—0.16	—0.24	+0.46
IX	—0.44	—0.02	+0.26	+0.12	—0.21	—1.01	+0.16	+0.27	—0.30	—0.18	+0.31
X	—0.52	+0.04	+0.25	+0.28	—0.37	—0.98	+0.07	+0.10	—0.26	—0.07	+0.36
XI	—0.52	—0.05	+0.34	+0.33	—0.38	—0.99	+0.09	+0.15	—0.16	—0.15	+0.32
XII	—0.70	+0.31	+0.28	+0.12	—0.47	—1.09	+0.09	+0.06	—0.15	—0.16	+0.45
XIII	—0.64	+0.03	+0.21	+0.16	—0.35	—0.91	+0.16	+0.19	—0.27	—0.11	+0.30
XIV	—0.50	+0.06	+0.27	+0.21	—0.42	—1.07	+0.09	—0.03	—0.22	—0.09	+0.42
Means.	—0″.49	+0″.06	+0″.19	+0″.16	—0″.25	—1″.01	+0″.09	+0″.23	—0″.17	—0″.14	+0″.36

From the Declinations:

Plate.	Star 1.	Star 2.	Star 4.	Star 5.	Star 9.	Star 10.	Star 14.	Star 15.	Star 21.	Star 22.	Star 23.
I			—0″.21	+0″.11	+0″.07	+0″.34	—0″.12	+0″.53	+0″.20	—0″.15	+0″.17
II	+0″.28	—0″.19	—0.08	—0.21	+0.26	+0.31	—0.08	+0.52	+0.17	—0.07	+0.16
III	+0.22	—0.07	—0.11	—0.12	+0.23	+0.33	—0.17	+0.58	+0.22	+0.03	+0.11
IV	+0.12	+0.03	—0.09	+0.08	—0.15	+0.16	—0.18	+0.21	+0.22	—0.01	+0.23
V	+0.08	—0.06	—0.05	—0.02	+0.01	+0.13	—0.10	+0.16	+0.16	—0.10	+0.29
VI	+0.09	—0.08	—0.01	—0.08	+0.03	+0.27	—0.16	+0.13	+0.21	+0.08	+0.16
VII	—0.14	—0.06	—0.01	—0.14	+0.25	+0.18	—0.08	+0.03	+0.11	+0.13	+0.03
VIII	+0.24	—0.06	—0.03	—0.01	+0.11	+0.07	—0.18	+0.14	+0.30	—0.03	+0.17
IX	—0.03	—0.06	—0.09	+0.05	+0.08	+0.19	—0.10	.00	+0.10	.00	+0.19
X	—0.10	—0.01	—0.02	—0.12	—0.12	+0.20	—0.06	—0.07	+0.20	—0.01	+0.24
XI	—0.02	—0.13	—0.13	—0.06	—0.04	+0.18	—0.09	+0.23	+0.15	+0.04	+0.19
XII	+0.01	—0.13	—0.07	—0.02	+0.14	+0.19	—0.11	+0.09	+0.24	—0.07	+0.23
XIII	.00	—0.09	—0.03	—0.08	+0.18	+0.32	—0.11	—0.01	+0.11	+0.06	+0.12
XIV	—0.09	—0.06	—0.14	—0.14	+0.06	+0.17	—0.02	+0.05	+0.10	+0.04	+0.12
Means	+0″.05	—0″.07	—0″.08	—0″.05	+0″.10	+0″.22	—0″.11	+0″.18	+0″.18	0″.00	+0″.17

A consideration of these residuals brings out several interesting facts. In the first place it is evident that they are almost entirely due to errors in the meridian places, as the residuals from the different plates for any one star run very nearly alike. But a more important matter is their size. On the whole they are fairly large, although perhaps not more so than might have been expected from the probable errors of the standard stars. At least is this the case with the declinations; the right ascensions show a much greater uncertainty. This is due partly to the fact that x's on the plates are more difficult to measure, owing to the elongation of the images; but the chief cause is the greater inaccuracy of the catalogue right ascensions. The statement regarding this matter in Part I, Sect. I, "WEIGHTS," is thus fully borne out. It is important to note, that the residuals seem to increase more rapidly than the probable errors of the stars, so that the poorly determined standards show relatively larger residuals than the others. These considerations lead to the following conclusions: Unless several stars on the plates can be found well determined in a considerable number of reliable catalogues, it will not pay to go through the laborious process of obtaining the positions of the standards by the method which I employed. If good modern observations are available, the constants determined from them will be quite sufficiently accurate; provided, of course, that the date of observation is not very distant from the date of exposure of the plate, or otherwise, that the proper motion of the stars be accurately known.

To satisfy myself on this point, I deduced the constants of Plate III, using values of n_x and n_y obtained by comparison of nine of my stars with Romberg's places. The weights assigned were the same as had been given to this catalogue throughout the present paper. I found thus:

$$k = -0.''469 \pm 0.''107$$
$$c = -0.''256 \pm 0.''107$$
$$p = +0.000433 \pm 0.000061$$
$$r = +0.000245 \pm 0.000061$$

and the residuals:

	Star 1.	Star 2.	Star 4.	Star 5.	Star 14.	Star 15.	Star 21.	Star 22.	Star 23.
In α	$-0''.65$	$+0''.25$	$+1''.10$	$+0''.69$	$-0''.47$	$-0''.21$	$+0''.67$	$-0''.35$	$+0''.36$
In δ	$+0.03$	$+0.18$	-0.23	$+0.06$	-0.26	$+0.28$	$+0.37$	$+0.07$	$+0.06$

Both the residuals and the probable errors, it is true, are rather larger than when the constants were obtained by the more elaborate method. But considering the quantities themselves, it will be seen, that both p and k differ from the values previously obtained by more than the sums of the probable errors. In the latter case, the reason for this discrepancy is an unexplained systematic difference between Romberg's places, and the positions of my standards. The discordance in p cannot be thus explained. It is much more serious, as it affects, not the group as a whole, but changes the relative positions of the stars. It appears then, that the constants are by far the most unreliable of all the quantities used in the reduction of the plates; and it would seem that any labor spent on them, outside of what is absolutely necessary, is but poorly repaid.

True Scale-Value.—It has been stated that the computed scale-value, $52''.87(1+p)$, involves the effect of aberration. It may be useful for future reductions of the Rutherfurd photographs to set down the true quantities. Although for accurate work it will in general be necessary to perform the least square solution for each plate, and thus independently to obtain the scale-value, cases might arise, when a close approximation would be sufficient, or when the number of available standards is so small, that no reliance can be placed on the resulting constants. Then, too, it is possible that a relation may exist between the "focus" and the scale-value.

To find the form of the correction to be added to $52''.87(1+p)$ in order to eliminate the effect of aberration, we let

$\sigma =$ the *true* distance in seconds of arc, from the center to any star on the plate;

$n =$ the *measured* number of millimeters on the plate, from the center to the star whose distance is σ.

Then it is evident, from the method by which the constants are derived (*i. e.*, by comparison with catalogue positions) that, but for errors of observation,

$$\frac{\sigma}{n} = 52''.87(1 + p). \qquad (1)$$

But evidently, n is too great by the amount of the aberration, being the measured distance on the plate. Hence, if we let

$$\gamma = -(\tan\varepsilon \sin\delta_0 + \sin\alpha_0 \cos\delta_0) \cdot \sin 1''$$
$$\delta = \cos\alpha_0 \cos\delta_0 \cdot \sin 1'',$$

where ε is the obliquity of the ecliptic, and α_0 and δ_0 are the coördinates of the central star, roughly corrected to the time of exposure of the plate, then will (cf. Chauvenet, Astronomy, Vol. II, p. 467)

$$\sigma(1 + C\gamma + D\delta)$$

be the measured distance on the plate in seconds of arc. C and D in this formula represent the Besselian day numbers, and may be obtained from the Ephemeris. We find, then, evidently

$$\text{True Scale-Value} = S = \frac{\sigma(1 + C\gamma + D\delta)}{n} \qquad (2)$$

or, remembering equation (1), and neglecting small terms

$$S = 52''.87(1 + p + C\gamma + D\delta). \qquad (3)$$

A correction for the temperature at which the plate was measured might also be applied, using for this purpose the coefficient of expansion determined by Dr. Schlesinger ("Præsepe," p. 223). But as that quantity is not very reliable, and as the corrections are necessarily very small, being in no case as large as 0.0007 if we use the value of v as given in the place referred to, while, on the other hand, the mean uncertainty of p is more than 0.0013, I have felt justified in neglecting the same.

We obtain then the following table :

Table X.—True Scale Values.

Plate.	$1+p$.	Corr. for Aberr.	Corr. Scale Value.	Tel. Ther.	Focus.
I	+1.000240	+0.000062	52″.8860	53°	8.4
II	+ 238	+ 062	52.8859	53	8.4
III	+ 308	+ 063	52.8896	58	8.5
IV	+ 233	+ 088	52.8870	60	7.7
V	+ 265	+ 088	52.8887	60	7.7
VI	+ 260	+ 088	52.8884	60	7.7
VII	+ 210	+ 088	52.8858	70	7.6
VIII	+ 215	+ 088	52.8860	70	7.6
IX	+ 290	+ 086	52.8899	60	7.7
X	+ 283	+ 086	52.8895	60	7.7
XI	+ 307	+ 086	52.8908	60	7.7
XII	+ 266	+ 086	52.8886	60	7.7
XIII	+ 307	+ 086	52.8908	65	7.65
XIV	+ 304	+ 086	52.8906	65	7.65

The mean scale-value is:

52″.8884.

In forming the above table no account has been taken of the temperature at which the plate was exposed, nor of the reading of the "focus" and "telescopic thermometer" (which are copied from TABLE I). A discussion of the effects of these causes on the scale-value must be postponed until a much larger number of Rutherfurd plates have been independently reduced.

Separate Results.—Employing the constants of TABLE IX as explained in Sect. III, we obtain the "projected" right ascensions and declinations, α_1 and δ_1, given on the succeeding pages. From them we can find the final coördinates, α and δ, and the proper motions. The latter were deduced from my results, in connection with Chase's (cf. p. 343, foot-note, of the present paper) positions, for all those stars which he observed. Only two others were found on a sufficient number of plates to warrant an investigation for proper motion. The method employed for all cases when the observations were distributed over more than two distinct dates, was that fully explained in Part I, Sect. II, "FORMULÆ FOR ADJUSTMENT." The epoch being 1875, Chase's positions were reduced from 1892 to that date, using his geometric precessions. A systematic correction of – 0″.44 in R. A. and + 0″.72 in Decl., indicated by direct comparison with my standards, was then applied. As date of observation I assumed uniformly 1891.6. This differs in no case by more than .3 of a year from the true value, and the calculations are greatly simplified by using the same dates throughout, as then T_0 and $\Sigma(CD)$ remain constant. Unit weight was assigned to all the observations, including those of Chase. This was warranted by the probable errors, and the formulæ of Part I, p. 365 were greatly simplified thereby. They become

$$a_0 = \frac{\Sigma(B)}{m} - \beta, \quad T_0 = \frac{\Sigma(t)}{m} - \beta'$$

and

$$\Delta\mu_0 = \frac{\Sigma(CE)}{\Sigma(C^2)}, \quad \mu = -\Delta\mu_0,$$

where the notation is the same as before and m denotes the number of observations. The α_0 and δ_0 thus obtained include Chase's position, however. As I wished to have an independent determination, deduced solely from the photographic observations, these quantities were not used, but a value for 1875 was obtained directly by the following method: The proper motion having been found as explained above, the measured positions were corrected to 1875 by applying to them the quantity $\mu(1875 - t)$. The mean was then taken of the corrected places excluding Chase's position, and this is the final "projected" coördinate for 1875, *i. e.*, α_1 or δ_1, as the case may be, of the succeeding tables. The probable error of a single observation was obtained from all the residuals by Peters' formula as given by Rogers in his zone (North Decl. 50° to 55°) of the *Catalog der Astronomischen Gesellschaft*, p. (10), which is

$$r = \pm 0.8453 \frac{[+v]}{\sqrt{n(n - n'')}},$$

n being the total number of residuals used, and n'' being the number of stars. We find thus

$$r_\alpha = \pm 0''.0939 = \pm 0''.0840 \text{ in equatorial seconds,}$$
$$r_\delta = \pm 0''.0595,$$

as the probable error of a single observation. The probable error of a catalogue position depending on fourteen plates is therefore

$$r_a = \pm 0''.025, \qquad r_\delta = \pm 0''.016,$$

the r_a being in seconds of arc of a parallel of declination through the center of the plate. It should be mentioned, that the residuals as used are assumed to be all of equal weight. This, while not theoretically correct (since some of the positions include, besides errors of direct observation, the uncertainty of the proper motion) is sufficiently accurate, owing to the small value of the probable errors of the proper motions, and the fact that $(1875-t)$ is in no case larger than 4.7.

The probable errors of the proper motions were obtained by the usual formulæ (cf. Part I, Sect. II, "FORMULÆ FOR ADJUSTMENT")

$$r_1 = \pm 0.6745 \sqrt{\frac{[vv]}{m-2}}, \qquad r_\mu = \frac{r_1}{\sqrt{[C^2]}}.$$

The v's used here were the same as before, including, however, the residuals obtained from Chase's position reduced to 1875 and corrected for proper motion. Neglecting the fact that the mean a_1 or δ_1 does not include Chase's observations, which can be done without appreciable effect on the result, it is easy to show that the residuals obtained as explained above have the same value as they would have if computed by the method described in Part I, Sect. III, "STAR TABLES." For by the latter method

$$\begin{aligned} v_a &= a_0 - B_a' \\ &= \frac{a_1 + a_2 + \cdots + a_m}{m} \\ &\qquad - \left[a_1 + \Delta\mu_0 \frac{mt_1 - (t_1 + t_2 + \cdots + t_m)}{m} \right] \\ &= \frac{a_1 + a_2 + \cdots + a_m}{m} + \frac{\Delta\mu_0 (t_1 + t_2 + \cdots + t_m)}{m} \\ &\qquad - a_1 - \Delta\mu_0 t_1 \end{aligned}$$

for the case of equal weights of all the α's. But by the first method

$$v_a = \frac{a_1 + \Delta\mu_0(t_1 - 1875) + a_2 + \Delta\mu_0(t_2 - 1875) + \cdots + a_m + \Delta\mu_0(t_m - 1875)}{m}$$

$$- [a_1 + \Delta\mu_0 (t_1 - 1875)]$$

$$= \frac{a_1 + a_2 + \cdots + a_m}{m} + \frac{\Delta\mu_0(t_1 + t_2 + \cdots + t_m)}{m} - a_1 - \Delta\mu_0 t_1 ,$$

so that the two results are identical. We can therefore use the formula for r_μ given above, and, with the exception of the slight inaccuracy mentioned, the results will be theoretically correct. All the probable errors of the proper motion in the succeeding tables were obtained in this way.

On the following pages are recorded the separate positions of all the stars on the plates. Chase's place, reduced to 1875, is printed in Italics at the end of each list. The headings are plain when taken in connection with the preceding discussion. At the end of each table are given the final means, α_1 and δ_1, the date of observation, and the proper motion with its probable error. α_1 and δ_1, as has been stated, do not include Chase's observations. For the stars numbered 1, 2, 4, 5, 6, 7, 8, 9, 10, 14, 15, 21, 22, 23, and 24, μ and μ' were computed by the method detailed above. The other proper motions given in the tables were obtained by subtracting the mean of my determinations from Chase's position, and dividing the difference by the interval in years. They are inclosed in brackets, for the sake of distinction. No probable error was computed for them. The dates of observation are evidently the same in all cases, and are as follows: Plates I–III, 1870.3, Plates IV–VIII, 1875.4, Plates IX–XIV, 1876.4, and Chase 1891.6. They are not repeated in the tables, but at the end of each is given the mean date of observation (excluding Chase) corresponding to the star.

STAR 1.

Plate	Right Ascension.				Declination.			
	At Epoch of Plate.	Corr. for μ.	Epoch 1875.	v.	At Epoch of Plate.	Corr. for μ′.	Epoch 1875.	v.
	° ′ ″	″	″	″	° ′ ″	″	″	″
II	183 5 52.74	−0.33	52.41	+0.63	26 53 9.81	+0.34	10.15	−0.17
III	5 53.36	−0.33	53.03	+0.01	53 9.75	+0.34	10.09	−0.11
IV	5 53.23	+0.03	53.26	−0.22	53 10.08	−0.03	10.05	−0.07
V	5 53.06	+0.03	53.09	−0.05	53 10.04	−0.03	10.01	−0.03
VI	5 53.09	+0.03	53.12	−0.08	53 10.05	−0.03	10.02	−0.04
VII	5 53.13	+0.03	53.16	−0.12	53 9.82	−0.03	9.79	+0.19
VIII	5 53.11	+0.03	53.14	−0.10	53 10.19	−0.03	10.16	−0.18
IX	5 53.08	+0.10	53.18	−0.14	53 10.00	−0.10	9.90	+0.08
X	5 52.99	+0.10	53.09	−0.05	53 9.95	−0.10	9.85	+0.13
XI	5 52.98	+0.10	53.08	−0.04	53 10.03	−0.10	9.93	+0.05
XII	5 52.78	+0.10	52.88	+0.16	53 10.05	−0.10	9.95	+0.03
XIII	5 52.86	+0.10	52.96	+0.08	53 10.04	−0.10	9.94	+0.04
XIV	5 52.99	+0.10	53.09	−0.05	53 9.96	−0.10	9.86	+0.12
Chase	*5 51.66*	*+1.16*	*52.82*	*+0.22*	*53 11.31*	*−1.21*	*10.10*	*−0.12*
a_1			**183° 5′ 53″.01**		δ_1		**26° 53′ 9″.98**	
Date of Observation,			1875.1		Date of Observation,		1875.1	
μ			**−0″.070** ±0″.0085		μ'		**+0″.073** ±0″.0046	

STAR 2.

Plate.	Right Ascension.				Declination.			
	At Epoch of Plate.	Corr. for μ.	Epoch 1875.	v.	At Epoch of Plate.	Corr. for μ′.	Epoch 1875.	v.
	° ′ ″	″	″	″	° ′ ″	″	″	″
II	183 11 0.62	−0.18	0.44	−0.11	26 42 20.11	+0.04	20.15	+0.03
III	11 0.43	−0.18	0.25	+0.08	42 20.22	+0.04	20.26	−0.08
IV	11 0.48	+0.02	0.50	−0.17	42 20.27	.00	20.27	−0.09
V	11 0.39	+0.02	0.41	−0.08	42 20.20	.00	20.20	−0.02
VI	11 0.37	+0.02	0.39	−0.06	42 20.17	.00	20.17	+0.01
VII	11 0.30	+0.02	0.32	+0.01	42 20.19	.00	20.19	−0.01
VIII	11 0.34	+0.02	0.36	−0.03	42 20.18	.00	20.18	.00
IX	11 0.15	+0.05	0.20	+0.13	42 20.18	−0.01	20.17	+0.01
X	11 0.21	+0.05	0.26	+0.07	42 20.24	−0.01	20.23	−0.05
XI	11 0.11	+0.05	0 16	+0.17	42 20.12	−0.01	20.11	+0.07
XII	11 0.49	+0.05	0.54	−0.21	42 20.11	−0.01	20.10	+0.08
XIII	11 0.19	+0.05	0.24	+0.09	42 20.15	−0.01	20.14	+0.04
XIV	11 0.23	+0.05	0.28	+0.05	42 20.18	−0.01	20.17	+0.01
Chase	*10 59.71*	*+0.65*	*0.36*	*−0.03*	*42 20.34*	*−0.13*	*20.21*	*−0.03*
a_1			**183° 11′ 0″.33**		δ_1		**26° 42′ 20″.18**	
Date of Observation,			1875.1		Date of Observation,		1875.1	
μ			**−0″.039** ±0″.0045		μ'		**+0″.008** ±0″.002 0	

STAR 3.

Plate.	Right Ascension.				Declination.			
	At Epoch of Plate.	Corr. for μ.	Epoch 1875.	v.	At Epoch of Plate.	Corr. for μ'.	Epoch 1875.	v.
VI	183° 13′ 56″.61	0″.00	56″.61	—	25° 45′ 25″.94	—0″.01	25″.93	—
Chase	*13 56.79*	*—0.18*	*56.61*	—	*45 26.28*	*—0.35*	*25.93*	—
α_1		**183° 13′ 56″.61**			δ_2		**25° 45′ 25″.93**	
Date of Observation,		1875.4			Date of Observation,		1875.4	
μ		[+0″.011]			μ		[+0″.021]	

STAR 4.

Plate.	Right Ascension.				Declination.			
	At Epoch of Plate.	Corr. for μ.	Epoch 1875.	v.	At Epoch of Plate.	Corr. for μ'.	Epoch 1875.	v.
I	183° 30′ 20″.48	—0″.85	19″.63	—0″.07	26° 41′ 46″.42	+0″.17	46″.59	+0″.10
II	30 20.43	—0.85	19.58	—0.02	41 46 55	+0.17	46.72	—0.03
III	30 20.27	—0.85	19 42	+0.14	41 46.51	+0.17	46.68	+0.01
IV	30 19.58	+0.07	19.65	—0.09	41 46.69	—0.01	46.68	+0.01
V	30 19.48	+0.07	19.55	+0.01	41 46.73	—0.01	46.72	—0.03
VI	30 19.45	+0.07	19.52	+0.04	41 46.76	—0.01	46.75	—0.06
VII	30 19.36	+0.07	19.43	+0.13	41 46.76	—0.01	46.75	—0.06
VIII	30 19.43	+0.07	19.50	+0.06	41 46.75	—0.01	46.74	—0.05
IX	30 19.34	+0.25	19.59	—0.03	41 46.71	—0.05	46.66	+0.03
X	30 19.33	+0.25	19 58	—0.02	41 46.79	—0.05	46.74	—0.05
XI	30 19.43	+0.25	19 68	—0.12	41 46.68	—0.05	46.63	+0.06
XII	30 19.36	+0.25	19 61	—0.05	41 46.74	—0.05	46.69	0.00
XIII	30 19.30	+0.25	19.55	+0.01	41 46.77	—0.05	46.72	—0.03
XIV	30 19.36	+0.25	19.61	—0.05	41 46.66	—0.05	46.61	+0.08
Chase	*30 16.52*	*+3.00*	*19.52*	*+0.04*	*41 47.26*	*—0.60*	*46.66*	*+0.03*
α_1		**183° 30′ 19″.56**			δ_1		**26° 41′ 46″.69**	
Date of Observation,		1874.7			Date of Observation,		1874.7	
μ		**—0″.181** ±0″.0028			μ'		**+0″.036** ±0″.0019	

STAR 5.

Plate.	Right Ascension.				Declination.			
	At Epoch of Plate.	Corr. for μ.	Epoch 1875.	v.	At Epoch of Plate.	Corr. for μ′.	Epoch 1875.	v.
I	183° 30′ 51″.28	—0″.42	50″.86	+0″.37	27° 19′ 6″.84	—0″.45	6″.39	—0″.21
II	30 51.72	—0.42	51.30	—0.07	19 6.52	—0.45	6.07	+0.11
III	30 51.72	—0.42	51.30	—0.07	19 6.62	—0.45	6.17	+0.01
IV	30 51.28	+0.04	51.32	—0.09	19 6.27	+0.04	6.31	—0.13
V	30 51.24	+0.04	51.28	—0.05	19 6.18	+0.04	6.22	—0.04
VI	30 51.13	+0.04	51.17	+0.06	19 6.12	+0.04	6.16	+0.02
VII	30 51.12	+0.04	51.16	+0.07	19 6.06	+0.04	6.10	+0.08
VIII	30 51.31	+0.04	51.35	—0.12	19 6.18	+0.04	6.22	—0.04
IX	30 51.04	+0.13	51.17	+0.06	19 6.12	+0.13	6.25	—0.07
X	30 51.20	+0.13	51.33	—0.11	19 5.96	+0.13	6.09	+0.09
XI	30 51.26	+0.13	51.39	—0.17	19 6.01	+0.13	6.14	+0.04
XII	30 51.02	+0.13	51.15	+0.08	19 6.07	+0.13	6.20	—0.02
XIII	30 51.07	+0.13	51.20	+0.03	19 6.00	+0.13	6.13	+0.05
XIV	30 51.11	+0.13	51.24	—0.01	19 5.94	+0.13	6.07	+0.11
Chase	*30 49.65*	*+1.49*	*51.14*	*—0.09*	*19 4.63*	*+1.59*	*6.22*	*—0.04*
α_1			**183° 30′ 51″.23**		δ_1		**27° 19′ 6″.18**	
Date of Observation,			1874.7		Date of Observation,		1874.7	
μ			**—0″.090** ±0″.0049		μ′		**—0″.096** ±0″.0034	

STAR 6.

Plate.	Right Ascension.				Declination.			
	At Epoch of Plate.	Corr. for μ.	Epoch 1875.	v.	At Epoch of Plate.	Corr. for μ′.	Epoch 1875.	v.
I	183° 36′ 56″.99	—0″.30	56″.69	—0″.21	26° 27′ 38″.54	+0″.02	38″.56	+0″.14
II	36 56.91	—0.30	56.61	—0.13	27 38.85	+0.02	38.87	—0.17
III	36 56.47	—0.30	56.17	+0.31	27 38.71	+0.02	38.73	—0.03
IV	36 56.51	+0.03	56.54	—0.06	27 38.62	.00	38.62	+0.08
V	36 56.49	+0.03	56.52	—0.04	27 38.61	.00	38.61	+0.09
VI	36 56.41	+0.03	56.44	+0.04	27 38.63	.00	38.63	+0.07
VII	36 56.02	+0.03	56.05	+0.43	27 38.65	.00	38.65	+0.05
VIII	36 56.77	+0.03	56.80	—0.32	27 38.75	.00	38.75	—0.05
X	36 56.58	+0.09	56.67	—0.19	27 38.82	—0.01	38.81	—0.11
XI	36 56.18	+0.09	56.27	+0.21	27 38.77	—0.01	38.76	—0.06
XII	36 56.38	+0.09	56.47	+0.01	27 38.71	—0.01	38.70	.00
XIII	36 56.67	+0.09	56.76	—0.28	27 38.68	—0.01	38.67	+0.03
XIV	36 56.23	+0.09	56.32	+0.16	27 38.79	—0.01	38.78	—0.08
α_1			**183° 36′ 56″.48**		δ_1		**26° 27′ 38″.70**	
Date of Observation,			1874.6		Date of Observation,		1874.6	
μ			**—0″.064** ±0″.0187		μ′		**+0″.004** ±0″.0073	

STAR 7.

Plate.	Right Ascension.				Declination.			
	At Epoch of Plate.	Corr. for μ.	Epoch 1875.	v.	At Epoch of Plate.	Corr. for μ'.	Epoch 1875.	v.
I	183° 38′ 53″.30	—0″.12	53″.18	—0″.08	26° 37′ 16″.63	—0″.02	16″.61	+0″.07
II	38 53.25	—0.12	53.13	—0.03	37 16.71	—0.02	16.69	—0.01
III	38 53.14	—0.12	53.02	+0.08	37 16.80	—0.02	16.78	—0.10
IV	38 53.22	+0.01	53.23	—0.13	37 16.58	.00	16.58	+0.10
V	38 53.11	+0.01	53.12	—0.02	37 16.76	.00	16.76	—0.08
VI	38 53.03	+0.01	53.04	+0.06	37 16.80	.00	16.80	—0.12
VII	38 52.89	+0.01	52.90	+0.20	37 16.67	.00	16.67	+0.01
VIII	38 53.23	+0.01	53.24	—0.14	37 16.71	.00	16.71	—0.03
IX	38 52.91	+0.04	52.95	+0.15	37 16.50	+0.01	16.51	+0.17
X	38 53.04	+0.04	53.08	+0.02	37 16.66	+0.01	16.67	+0.01
XI	38 53.23	+0.04	53.27	—0.17	37 16.81	+0.01	16.82	—0.14
XII	38 53.09	+0.04	53.13	—0.03	37 16.79	+0.01	16.80	—0.12
XIII	38 53.18	+0.04	53.22	—0.12	37 16.49	+0.01	16.50	+0.18
XIV	38 52.88	+0.04	52.92	+0.18	37 16.63	+0.01	16.64	+0.04
Chase	*38 52.70*	*+0.42*	*53.12*	*—0.02*	*37 16.63*	*+0.07*	*16.70*	*—0.02*

a_1 **183° 38′ 53″.10** — δ_1 **26° 37′ 16″.68**

Date of Observation, 1874.7 — Date of Observation, 1874.7

μ **—0″.025** ±0″.0044 — μ' **—0″.004** ±0″.0038

STAR 8.

Plate.	Right Ascension.				Declination.			
	At Epoch of Plate.	Corr. for μ.	Epoch 1875.	v.	At Epoch of Plate.	Corr. for μ'.	Epoch 1875.	v.
I	183° 41′ 47″.75	—0″.27	47″.48	+0″.02	26° 24′ 55″.40	—0″.09	55″.31	—0″.13
II	41 47.78	—0.27	47.51	—0.01	24 55.30	—0.09	55.21	—0.03
III	41 47.44	—0.27	47.17	+0.33	24 55.37	—0.09	55.28	—0.10
IV	41 47.70	+0.02	47.72	—0.22	24 55.66	+0.01	55.17	+0.01
V	41 47.34	+0.02	47.36	+0.14	24 55.08	+0.01	55.09	+0.09
VI	41 47.57	+0.02	47.59	—0.09	24 55.20	+0.01	55.21	—0.03
VII	41 47.65	+0.02	47.67	—0.17	24 55.21	+0.01	55.22	—0.04
VIII	41 47.64	+0.02	47.66	—0.16	24 55.14	+0.01	55.15	+0.03
IX	41 47.29	+0.08	47.37	+0.13	24 55.09	+0.03	55.12	+0.06
X	41 47.34	+0.08	47.42	+0.08	24 55.07	+0.03	55.10	+0.08
XI	41 47.60	+0.08	47.68	—0.18	24 55.10	+0.03	55.13	+0.05
XII	41 47.36	+0.08	47.44	+0.06	24 55.23	+0.03	55.26	—0.08
XIII	41 47.27	+0.08	47.35	+0.15	24 55.18	+0.03	55.21	—0.03
XIV	41 47.43	+0.08	47.51	—0.01	24 55.07	+0.03	55.10	+0.08
Chase	*41 46.46*	*+0.95*	*47.41*	*+0.09*	*24 54.93*	*+0.33*	*55.26*	*—0.08*

a_1 **183° 41′ 47″.50** — δ_1 **26° 24′ 55″.18**

Date of Observation, 1874.7 — Date of Observation, 1874.7

μ **—0″.057** ±0″.0063 — μ' **—0″.020** ±0″.0027

STAR 9.

Plate.	Right Ascension.				Declination.			
	At Epoch of Plate.	Corr. for μ.	Epoch 1875.	v.	At Epoch of Plate.	Corr. for μ'.	Epoch 1875.	v.
	° ′ ″	″	″	″	° ′ ″	″	″	″
I	183 41 45.71	—1.36	44.35	—0.07	25 43 15.23	+0.63	15.86	+0.06
II	41 45.61	—1.36	44.25	+0.03	43 15.44	+0.63	16.07	—0.15
III	41 45.68	—1.36	44.32	—0.04	43 15.40	+0.63	16.03	—0.11
IV	41 44.37	+0.12	44.49	—0.21	43 15.76	—0.05	15.71	+0.21
V	41 44.16	+0.12	44.28	.00	43 15.92	—0.05	15.87	+0.05
VI	41 44.02	+0.12	44.14	+0.14	43 15.93	—0.05	15.88	+0.04
VII	41 44.23	+0.12	44.35	—0.07	43 16.16	—0.05	16.11	—0.19
VIII	41 44.34	+0.12	44.46	—0.18	43 16.01	—0.05	15.96	—0.04
IX	41 43.99	+0.40	44.39	—0.11	43 16.12	—0.19	15.93	—0.01
X	41 43.82	+0.40	44.22	+0.06	43 15.93	—0.19	15.74	+0.18
XI	41 43.80	+0.40	44.20	+0.08	43 16.01	—0.19	15.82	+0.10
XII	41 43.69	+0.40	44.09	+0.19	43 16.19	—0.19	16.00	—0.08
XIII	41 43 83	+0.40	44.23	+0.05	43 16.22	—0.19	16.03	—0.11
XIV	41 43.74	+0.40	44.14	+0.14	43 16.09	—0.19	15.90	+0.02
Chase	*41 39.53*	*+4.80*	*44.33*	*—0.05*	*43 18.19*	*—2.21*	*15.98*	*—0.06*
a_1			**183° 41′ 44″.28**		δ_1		**25° 43′ 15″.92**	
Date of Observation,			1874.7		Date of Observation,		1874.7	
μ			**—0″.289** ±0″.0044		μ'		**+0″.133** ±0″.0044	

STAR 10.

Plate.	Right Ascension.				Declination.			
	At Epoch of Plate.	Corr. for μ.	Epoch 1875.	v.	At Epoch of Plate.	Corr. for μ'.	Epoch 1875.	v.
	° ′ ″	″	″	″	° ′ ″	″	″	″
I	183 47 8.72	—0.18	8.54	—0.02	25 41 28.99	—0.07	28.92	—0.04
II	47 8.66	—0.18	8.48	+0.04	41 28.95	—0.07	28.88	.00
III	47 8.68	—0.18	8.50	+0.02	41 28.98	—0.07	28.91	—0.03
IV	47 8.73	+0.02	8.75	—0.23	41 28.82	+0.01	28.83	+0 05
V	47 8.44	+0.02	8.46	+0.06	41 28.80	+0.01	28.81	+0.07
VI	47 8.43	+0.02	8.45	+0 07	41 28.93	+0.01	28.94	—0.06
VII	47 8.33	+0.02	8.35	+0.17	41 28.85	+0.01	28.86	+0.02
VIII	47 8.71	+0.02	8.73	—0.21	41 28.74	+0.01	28.75	+0.13
IX	47 8.44	+0 05	8.49	+0.03	41 28.86	+0.02	28.88	.00
X	47 8.48	+0.05	8.53	—0.01	41 28.88	+0.02	28.90	—0.02
XI	47 8.48	+0.05	8.53	—0.01	41 28.86	+0.02	28.88	.00
XII	47 8.36	+0.05	8.41	+0.11	41 28.86	+0.02	28.88	.00
XIII	47 8.56	+0.05	8.61	—0.09	41 28.99	+0.02	29.01	—0.13
XIV	47 8.39	+0.05	8 44	+0.08	41 28.84	+0.02	28.86	+0.02
Chase	*47 7.87*	*+0.65*	*8.52*	*.00*	*41 28.66*	*+0.23*	*28.89*	*—0.01*
a_1			**183° 47′ 8″.52**		δ_1		**25° 41′ 28″.88**	
Date of Observation,			1874.7		Date of Observation,		1874.7	
μ			**—0″.039** ±0″.0041		μ'		**—0″.014** ±0″.0022	

STAR 11.

Plate.	Right Ascension. At Epoch of Plate.	Corr. for μ.	Epoch 1875.	v.	Declination. At Epoch of Plate.	Corr. for μ'.	Epoch 1875.	v.
	° ′ ″	″	″	″	° ′ ″	″	″	″
IV	183 51 50.55	+0.02	50.57	+0.02	27 18 8.60	—0.01	8.59	—0.53
VI	51 50.42	+0.02	50.44	+0.15	18 7.69	—0 01	7.68	+0.38
VIII	51 50.73	+0.02	50.75	—0.16	18 7.91	—0.01	7.90	+0.16
Chase	*51 49.89*	*+0.70*	*50.59*	*.00*	*18 8.28*	*—0.22*	*8.06*	*.00*
α_1			**183° 51′ 50″.59**		δ_1		**27° 18′ 8″.06**	
Date of Observation,			1875.4		Date of Observation,		1875.4	
μ			[— 0″.042]		μ'		[+0″.013]	

STAR 12.

Plate.	Right Ascension. At Epoch of Plate.	Corr. for μ.	Epoch 1875.	v.	Declination. At Epoch of Plate.	Corr. for μ'.	Epoch 1875.	v.
	° ′ ″		″	″	° ′ ″		″	″
IV	183 53 2.09	—	2.09	—0.05	27 14 35.44	—	35.44	+0.05
VI	53 1.84	—	1.84	+0.20	14 35.50	—	35.50	—0.01
VIII	53 2.19	—	2.19	—0.15	14 35.53	—	35.53	—0.04
α_1			**183° 53′ 2″.04**		δ_1		**27° 14′ 35″.49**	
Date of Observation,			1875.4		Date of Observation,		1875.4	
μ			?		μ'		?	

STAR 13.

Plate.	Right Ascension. At Epoch of Plate.	Corr. for μ.	Epoch 1875.	v.	Declination. At Epoch of Plate.	Corr. for μ'.	Epoch 1875.	v.
	° ′ ″		″	″	° ′ ″		″	″
IV	183 55 3.93	—	3.93	—0.16	26 22 46.96	—	46.96	—0.04
V	55 3.58	—	3.58	+0.19	22 46.85	—	46 85	+0.07
VI	55 3.68	—	3.68	+0.09	22 46.98	—	46.98	—0.06
VIII	55 3.90	—	3.90	—0.13	22 46.87	—	46 87	+0.05
α_1			**183° 55′ 3″.77**		δ_1		**26° 22′ 46″.9**	
Date of Observation,			1875.4		Date of Observation,		1875.4	
μ			?		μ'		?	

STAR 14.

Plate.	Right Ascension.				Declination.			
	At Epoch of Plate.	Corr. for μ.	Epoch 1875.	v.	At Epoch of Plate.	Corr. for μ'.	Epoch 1875.	v.
	° ′ ″	″	″	″	° ′ ″	°	″	″
I	184 3 18.34	—0.16	18.18	—0.05	26 32 23.83	+0.04	23.87	0.00
II	3 18.34	—0.16	18.18	—0.05	32 23.87	+0.04	23.91	—0.04
III	3 18.36	—0.16	18.20	—0.07	32 23.78	+0.04	23.82	+0.05
IV	3 17.94	+0.01	17.95	+0.18	32 23.80	.00	23.80	+0.07
V	3 18.02	+0.01	18.03	+0.10	32 23.88	.00	23.88	—0.01
VI	3 18 21	+0.01	18.22	—0.09	32 23.82	.00	23.82	+0.05
VII	3 18.18	+0.01	18.19	—0.06	32 23.90	.00	23.90	—0.03
VIII	3 18.00	+0.01	18.01	+0.12	32 23.80	.00	23.80	+0.07
IX	3 18.16	+0.05	18.21	—0.08	32 23.89	—0.01	23.88	—0.01
X	3 18.06	+0.05	18.11	+0.02	32 23.93	—0.01	23.92	—0.05
XI	3 18.08	+0.05	18.13	.00	32 23.90	—0.01	23.89	—0.02
XII	3 18.08	+0.05	18 13	.00	32 23 88	—0.01	23.87	.00
XIII	3 18.16	+0 05	18.21	—0.08	32 23.88	—0.01	23.87	.00
XIV	3 18.08	+0.05	18.13	.00	32 23.97	—0.01	23.96	—0.09
Chase	*3 17.62*	*+0.56*	*18.18*	*—0.05*	*32 24.01*	*—0.15*	*23.86*	*+0.01*
a_1			**184° 3′ 18″.13**		δ_1		**26° 32′ 23″.87**	
Date of Observation,			1874.7		Date of Observation,		1874.7	
μ			**—0″.034** ±0″.0031		μ'		**+0″.009** ±0″.0017	

STAR 15.

Plate.	Right Ascension.				Declination.			
	At Epoch of Plate.	Corr. for μ.	Epoch 1875.	v.	At Epoch of Plate.	Corr. for μ'.	Epoch 1875.	v.
	° ′ ″	″	″	″	° ′ ″	″	″	″
I	184 3 34 55	—0.13	34.42	+0.23	26 31 20.38	—0.03	20.35	+0.07
II	3 34.87	—0.13	34.74	—0 09	31 20.37	—0.03	20 34	+0.08
III	3 34.69	—0.13	34 56	+0 09	31 20.43	—0.03	20.40	+0.02
IV	3 34.68	+0.01	34.69	—0 04	31 20.52	.00	20.52	—0.10
V	3 34.85	+0.01	34.86	—0.21	31 20.45	.00	20.45	—0.03
VI	3 34.72	+0.01	34.73	—0.08	31 20.43	.00	20.43	—0.01
VII	3 34.54	+0.01	34.55	+0.10	31 20.34	.00	20.34	+0.08
VIII	3 34.97	+0.01	34.98	—0.33	31 20.44	.00	20.44	—0.02
IX	3 34.71	+0.04	34.75	—0.10	31 20.37	+0.01	20.38	+0.04
X	3 34.53	+0 04	34.57	+0.08	31 20.31	+0.01	20.32	+0.10
XI	3 34.58	+0.04	34.62	+0.03	31 20.61	+0.01	20.62	—0.20
XII	3 34.49	+0.04	34.53	+0.12	31 20.47	+0.01	20.48	—0.06
XIII	3 34.61	+0.04	34.65	.00	31 20.37	+0.01	20.38	+0.04
XIV	3 34.37	+0.04	34.41	+0.24	31 20.43	+0.01	20.44	—0.02
Chase	*3 34.14*	*+0.46*	*34.60*	*+0.05*	*31 0.23*	*+0.12*	*20.35*	*+0.07*
a_1			**184° 3′ 34″.65**		δ_1		**26° 31′ 20″.42**	
Date of Observation,			1874.7		Date of Observation,		1874.7	
μ			**—0″.028** ±0″.0058		μ'		**—0″.007** ±0″.0031	

STAR 16.

Plate.	Right Ascension.				Declination.			
	At Epoch of Plate.	Corr. for μ.	Epoch 1875.	v.	At Epoch of Plate.	Corr. for μ'.	Epoch 1875.	v.
	° ′ ″	″	″	″	° ′ ″	″	″	″
VI	184 4 25.98	+0.02	26.00	—0.10	27 18 57.12	+0.01	57.13	+0.12
VIII	4 25.77	+0.02	25.79	+0.11	18 57.35	+0.01	57.36	—0.11
Chase	*4 24.98*	*+0.92*	*25.90*	*.00*	*18 56.91*	*+0.34*	*57.25*	*.00*
α_1			**184° 4′ 25″.90**		δ_1		**27° 18′ 57″.25**	
Date of Observation,			1875.4		Date of Observation,		1875.4	
μ			[—0″.056]		μ'		[—0″.020]	

STAR 17.

Plate.	Right Ascension.				Declination.			
	At Epoch of Plate.	Corr. for μ.	Epoch 1875.	v.	At Epoch of Plate.	Corr. for μ'.	Epoch 1875.	v.
	° ′ ″		″	″	° ′ ″		″	″
IV	184 6 7.06	—	7.06	+0.12	26 30 1.31	—	1.31	+0.07
VIII	6 7.31	—	7.31	—0.13	30 1.45	—	1.45	—0.07
α_1			**184° 6′ 7″.18**		δ_1		**26° 30′ 1″.38**	
Date of Observation,			1875.4		Date of Observation,		1875.4	
μ			?		μ'		?	

STAR 18.

Plate.	Right Ascension.				Declination.			
	At Epoch of Plate.	Corr. for μ.	Epoch 1875.	v.	At Epoch of Plate.	Corr. for μ'.	Epoch 1875.	v.
	° ′ ″		″	″	° ′ ″		″	″
II	184 12 53.28	—	53.28	—0.18	26 32 42.56	—	42.56	—0.02
IV	12 53.31	—	53.31	—0.21	32 42.59	—	42.59	—0.05
V	12 53.20	—	53.20	—0.10	32 42.48	—	42.48	+0.06
VI	12 53.21	—	53.21	—0.11	32 42.52	—	42.52	+0.02
VII	12 52.51	—	52.51	+0.59	32 42.41	—	42.41	+0.13
VIII	12 53.58	—	53.58	—0.48	32 42.66	—	42.66	—0.12
X	12 53.15	—	53.15	—0.05	32 42.37	—	42.37	+0.17
XI	12 53.01	—	53.01	+0.09	32 42.61	—	42.61	—0.07
XII	12 52.78	—	52.78	+0.32	32 42.68	—	42.68	—0.14
XIV	12 52.96	—	52.96	+0.14	32 42.49	—	42.49	+0.05
α_1			**184° 12′ 53″.10**		δ_1		**26° 32′ 42″.51**	
Date of Observation,			1875.3		Date of Observation,		1875.3	
μ			?		μ'		?	

STAR 19.

Plate.	Right Ascension.				Declination.			
	At Epoch of Plate.	Corr. for μ.	Epoch 1875.	v.	At Epoch of Plate.	Corr. for μ'.	Epoch 1875.	v.
	° ′ ″		″	″	° ′ ″		″	″
II	184 18 12.71	—	12.71	—0.11	27 15 32.59	—	32.59	+0.16
V	18 12.48	—	12.48	+0.12	15 32.77	—	32.77	—0.02
VI	18 12.70	—	12.70	—0.10	15 32.72	—	32.72	+0.03
VIII	18 12.50	—	12.50	+0.10	15 32.92	—	32.92	—0.17
	α_1		**184° 18′ 12″.60**		δ_1		**27° 15′ 32″.75**	
	Date of Observation,		1874.1		Date of Observation,		1874.1	
	μ		?		μ'		?	

STAR 20.

Plate.	Right Ascension.				Declination.			
	At Epoch of Plate.	Corr. for μ.	Epoch 1875.	v.	At Epoch of Plate.	Corr. for μ'.	Epoch 1875.	v.
	° ′ ″		″		° ′ ″		″	
VIII	184 21 14.09	—	14.09	—	27 17 43.58	—	43.58	—
	α_1		**184° 21′ 14″.09**		δ_1		**27° 17′ 43″.58**	
	Date of Observation,		1875.4		Date of Observation,		1875.4	
	μ		?		μ'		?	

STAR 21.

Plate.	Right Ascension.				Declination.			
	At Epoch of Plate.	Corr. for μ.	Epoch 1875.	v.	At Epoch of Plate.	Corr. for μ'.	Epoch 1875.	v.
	° ′ ″	″	″	″	° ′ ″	″	″	″
I	184 26 44.13	—0.24	43.89	+0.05	26 32 42.76	0.00	42.76	+0.05
II	26 44.24	—0.24	44.00	—0.06	32 42.74	.00	42.74	+0.07
III	26 44.15	—0.24	43.91	+0.03	32 42.79	.00	42.79	+0.02
IV	26 44.17	+0.02	44.19	—0.25	32 42.87	.00	42.87	—0.06
V	26 44.03	+0.02	44.05	—0.11	32 42.81	.00	42.81	.00
VI	26 43.80	+0.02	43.82	+0.12	32 42.85	.00	42.85	—0.04
VII	26 43.77	+0.02	43.79	+0.15	32 42.76	.00	42.76	+0.05
VIII	26 43.94	+0.02	43.96	—0.02	32 42.93	.00	42.93	—0.12
IX	26 43.77	+0.07	43.84	+0.10	32 42.74	.00	42.74	+0.07
X	26 43.82	+0.07	43.89	+0.05	32 42.86	.00	42.86	—0.05
XI	26 43.90	+0.07	43.97	—0.03	32 42.80	.00	42.80	+0.01
XII	26 43.93	+0.07	44.00	—0.06	32 42.90	.00	42.90	—0.09
XIII	26 43.80	+0.07	43.87	+0.07	32 42.77	.00	42.77	+0.04
XIV	26 43.85	+0.07	43.92	+0.02	32 42.75	.00	42.75	+0.06
Chase	*26 43.09*	*+0.85*	*43.94*	*.00*	*32 42.75*	*+0.02*	*42.77*	*+0.04*

α_1	**184° 26′ 43.″94**	δ_1	**26° 32′ 42.″81**
Date of Observation,	1874.7	Date of Observation,	1874.7
μ	**—0.″051** ±0.″0038	μ'	**—0.″001** ±0.″0023

STAR 22.

Plate.	Right Ascension.				Declination.			
	At Epoch of Plate.	Corr. or μ.	Epoch 1875.	v.	At Epoch of Plate.	Corr. for μ'.	Epoch 1875.	v.
	° ′ ″	″	″	″	° ′ ″	″	″	″
I	184 30 29.08	—0.19	28.89	—0.03	26 47 33.51	+0.03	33.54	+0.10
II	30 29.16	—0.19	28.97	—0.11	47 33.60	+0.03	33.63	+0.01
III	30 29.06	—0.19	28.87	—0.01	47 33.69	+0.03	33.72	—0.08
IV	30 28.69	+0.02	28.71	+0.15	47 33.62	.00	33.62	+0.02
V	30 28.70	+0.02	28.72	+0.14	47 33.54	.00	33.54	+0.10
VI	30 28.84	+0.02	28.86	.00	47 33.72	.00	33.72	—0.08
VII	30 29.01	+0.02	29.03	—0.17	47 33.78	.00	33.78	—0.14
VIII	30 28.73	+0.02	28.75	+0.11	47 33.61	.00	33.61	+0.03
IX	30 28.75	+0.06	28.81	+0.05	47 33.63	—0.01	33.62	+0.02
X	30 28.88	+0.06	28.94	—0.08	47 33.62	—0.01	33.61	+0.03
XI	30 28.79	+0.06	28.85	+0.01	47 33.67	—0.01	33.66	—0.02
XII	30 28.78	+0.06	28.84	+0.02	47 33.56	—0.01	33.55	+0.09
XIII	30 28.83	+0.06	28.89	—0.03	47 33.69	—0.01	33.68	—0.04
XIV	30 28.87	+0.06	28.93	—0.07	47 33.67	—0.01	33.66	—0.02
Chase	*30 28.21*	*+0.68*	*28.89*	*—0.03*	*47 33.75*	*—0.12*	*33.63*	*+0.01*

α_1	**184° 30′ 28.″86**	δ_1	**26° 47′ 33.″64**
Date of Observation,	1874.7	Date of Observation,	1874.7
μ	**—0.″041** ±0.″0034	μ'	**+0.″007** ±0.″0026

STAR 23.

Plate.	Right Ascension. At Epoch of Plate.	Corr. for μ.	Epoch 1875.	v.	Declination. At Epoch of Plate.	Corr. for μ′.	Epoch 1875.	v.
I	184° 32′ 38″.57	—0″.23	38″.34	+0″.11	26° 16′ 36″.20	+0″.01	36″.21	+0″.07
II	32 38.55	—0.23	38.32	+0.13	16 36.20	+0.01	36.21	+0.07
III	32 38.63	—0.23	38.40	+0.05	16 36.14	+0.01	36.15	+0.13
IV	32 38.53	+0.02	38.55	—0.10	16 36.33	.00	36.33	—0.05
V	32 38.65	+0.02	38.67	—0.22	16 36.40	.00	36.40	—0.12
VI	32 38.38	+0.02	38.40	+0.05	16 36.28	.00	36.28	.00
VII	32 38.31	+0.02	38.33	+0.12	16 36.16	.00	36.16	+0.12
VIII	32 38.55	+0.02	38.57	—0.12	16 36.29	.00	36.29	—0.01
IX	32 38.33	+0.07	38.40	+0.05	16 36.32	.00	36.32	—0.04
X	32 38.39	+0.07	38 46	—0.01	16 36.36	.00	36.36	—0.08
XI	32 38.35	+0.07	38.42	+0.03	16 36.32	.00	36.32	—0.04
XII	32 38.49	+0.07	38.56	—0.11	16 36.35	.00	36.35	—0.07
XIII	32 38.31	+0.07	38.38	+0.07	16 36.24	.00	36.24	+0.04
XIV	32 38.46	+0.07	38.53	—0.08	16 36.24	.00	36.24	+0.04
Chase	*32 37.57*	*+0.80*	*38.37*	*+0.08*	*16 36.21*	*—0.03*	*36.18*	*+0.10*

a_1	**184° 32′ 38″.45**	δ_1	**26° 16′ 36″.28**
Date of Observation,	1874.7	Date of Observation,	1874.7
μ	**—0″.048** ±0″.0040	μ′	**+0″.002** ±0″.0030

STAR 24.

Plate.	Right Ascension. At Epoch of Plate.	Corr. for μ.	Epoch 1875.	v.	Declination. At Epoch of Plate.	Corr. for μ′.	Epoch 1875.	v.
I	184° 41′ 35″.82	—0″.35	35″.47	+0″.06	26° 15′ 18″.80	+0″.08	18″.88	—0″.04
II	41 35.90	—0.35	35.55	—0.02	15 18.73	+0.08	18.81	+0.03
III	41 35.87	—0.35	35.52	+0.01	15 18.75	+0.08	18.83	+0.01
IV	41 35.74	+0.03	35.77	—0.24	15 18.72	—0.01	18.71	+0.13
V	41 35.68	+0.03	35.71	—0.18	15 18.87	—0.01	18.86	—0.02
VI	41 35.60	+0.03	35.63	—0.10	15 18.72	—0.01	18.71	+0.13
VII	41 35.35	+0.03	35.38	+0.15	15 18.89	—0.01	18.88	—0.04
VIII	41 35.49	+0.03	35.52	+0.01	15 19.00	—0.01	18.99	—0.15
IX	41 35.16	+0.10	35.26	+0.27	15 18.90	—0.03	18.87	—0.03
X	41 35.45	+0.10	35.55	—0.02	15 18.87	—0.03	18.84	.00
XI	41 35 41	+0.10	35.51	+0.02	15 18.86	—0.03	18.83	+0.01
XII	41 35.41	+0.10	35.51	+0.02	15 18.91	—0.03	18.88	—0.04
XIII	41 35.39	+0.10	35.49	+0.04	15 18.78	—0.03	18.75	+0.09
XIV	41 35.42	+0.10	35.52	+0.01	15 18.90	—0.03	18.87	—0.03

a_1	**184° 41′ 35″.53**	δ_1	**26° 15′ 18″.84**
Date of Observation,	1874.7	Date of Observation,	1874.7
μ	**—0″.075** ±0″.0099	μ′	**+0″.018** ±0″.0059

Catalogue of Results.—In the "CATALOGUE OF STARS" on p. 477 are collected the final positions and proper motions deduced by me from the Rutherfurd Plates. The right ascensions and declinations are obtained from the α_1 and δ_1 given on the preceding pages by means of the formulæ

$$\alpha = \alpha_1 + T\alpha, \quad \delta = \delta_1 + T\delta,$$

T_α and T_δ being the transformation corrections. The columns are as follows:

1 gives my Number of the star;

2 gives Chase's Number;

3 gives the B. D. Number, and 4 the Magnitude of the star in that catalogue;

5 gives the Right Ascension for 1875 in degrees, minutes, and seconds of arc, reduced to the mean epoch *using the value of the proper motion* given in column 6.

7 and 8 give the corresponding quantities for the Declinations;

9 gives the Mean Date of Observation; and

10 gives the Number of Plates on which the position depends.

It may be well to repeat here that the probable error of a single observation is

$$r = \pm 0''.0939, \quad r\delta = \pm 0''.0595,$$

and of a position depending on fourteen plates

$$r\alpha = \pm 0''.025, \quad r\delta = \pm 0''.016.$$

Catalogue of 24 Stars of the Cluster in Coma Berenices.

Mean Equinox of 1875.0. **Epoch 1875.0.**

No.	Chase's No.	B. D. No.	B. D. Mag.	Right Ascen. 1875.0	Proper Mot. in R. A.	Declination 1875.0	Proper Mot. in Decl.	Mean Date of Observat.	No. of Plates used.
1	2	26°.2324	7.3	183° 5′ 42″.93	—0″.070	26° 52′ 58″.29	+0″.073	1875.1	13
2	3	26.2326	6.6	10 56.03	—0.039	26 42 10.58	+0.008	1875.1	13
3	4	25.2487	7.5	14 16.86	[+0.011]	25 45 17.90	[+0.021]	1875.4	1
4	5	26.2329	6.3	30 16.92	—0.181	26 41 42.87	+0.036	1874.7	14
5	6	27.2114	5.0	30 37.99	—0.090	27 19 2.21	—0.096	1874.7	14
6		26.2330	8.9	36 57.60	—0 064	26 27 36.29	+0.004	1874.6	13
7	8	26.2331	8.3	38 52.08	—0.025	26 37 14.60	—0.004	1874.7	14
8	9	26.2332	8.2	41 48.91	—0.057	26 24 53.58	—0.020	1874.7	14
9	10	25.2493	7.2	41 53.47	—0.289	25 43 14.55	+0.133	1874.7	14
10	11	25.2495	7.5	47 15.64	—0.039	25 41 28.22	—0.014	1874.7	14
11	12	27.2116	8.0	51 46.01	[—0.042]	27 18 7.43	[+0.013]	1875.4	3
12		27.2117	8.9	52 58.26	——	27 14 34.99	——	1875.4	3
13		26.2336	9.0	183 55 4.46	——	26 22 46.69	——	1875.4	4
14	d	26.2337	5.0[1]	184 3 18.13	—0.034	26 32 23.87	+0.009	1874.7	14
15	14	26.2338	8.5	3 34.65	—0.028	26 31 20.42	—0.007	1874.7	14
16	15	27.2118	7.8	4 26.37	[—0.056]	27 18 57.07	[—0.020]	1875.4	2
17		26.2339	9.1	6 7.12	——	26 30 1.35	——	1875.4	2
18		26.2340	8.6	12 53.13	——	26 32 42.22	——	1875.3	10
19		27.2120	8.8	18 18.24	——	27 15 31.81	——	1874.1	4
20		27.2121	9.0	21 21.23	——	27 17 42.26	——	1875.4	1
21	18	26.2343	7.0	26 43.99	—0.051	26 32 40.89	—0.001	1874.7	14
22	19	26.2344	5.3[1]	30 32.43	—0.041	26 47 31.03	+0.007	1874.7	14
23	20	26.2345	6.3	32 34.39	—0.048	26 16 33.32	+0.002	1874.7	14
24		26.2347	8.3	41 29.75	—0.075	26 15 13.79	+0.018	1874.7	14

[1] May be variable. Cf. Köhl in Astr. Soc. of the Pacific, Publications, Vol. X, no. 60, p. 24.

On the foregoing pages have been recorded the measures and methods of reduction leading to the "CATALOGUE OF STARS," p. 477. In general it will be better to measure a large number of plates with less elaboration than has been done in the present case. But owing to the very small number of existing photographs of so early a date it was necessary, in order to get the best results, to employ all possible precaution to guard against errors. The excellent agreement between Chase's determinations and the photographic positions speaks well for the accuracy of both researches. The proper motions cannot, of course, be verified until a later date, but it seems safe to assume that all of those depending on fourteen plates and on Chase's observations are very nearly correct. It is to be regretted that their number is not larger. The group is not well adapted to photographic work, however. The range of magnitudes is large and the stars are very scattered. In fact, it may be doubted whether the term Group may properly be applied to these stars. The proper motions certainly do not indicate any physical connection. This matter, however, is of ulterior interest.

In conclusion, I wish again to thank Messrs. Schlesinger and Hays for aiding me in measuring the plates; Dr. Davis for invaluable assistance in the catalogue work, and for freely placing at my disposal his experience in all matters connected therewith; Professor Jacoby for his ever-ready counsel on all difficult points, and Professor Rees, Director of the Observatory, for the interest he has shown in the work, and for securing its publication. It may also be mentioned that free use has been made of the Observatory Contributions, especially of Dr. Davis' "Fifty-Six Stars" and of Dr. Schlesinger's "Præsepe."

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New York
Academy of Sciences

SEVENTH ANNUAL RECEPTION.

April 25 and 26, 1900.

CATALOGUE

Of Exhibits.

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1900

Seventh Annual Reception and Exhibit of Recent Progress in Science

at the

American Museum of Natural History.

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RECEPTION TO MEMBERS OF ACADEMY AND INVITED GUESTS,
8–10 P. M.

THURSDAY, APRIL 26:
AFTERNOON EXHIBIT, 3–5 P. M.
EVENING RECEPTION, TO MEMBERS OF THE SCIENTIFIC ALLIANCE,
8–10 P. M.

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FOUNDED IN 1817.

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PUBLICATIONS.

The publications of the Academy at present consist of two series—*The Annals* (octavo) and *The Memoirs* (quarto). All are distributed to Members and Fellows, and are circulated in exchange for the publications of nearly all the foreign and American Academies and learned Societies. The Annals, which opened in 1824, contain the longer contributions and reports of researches, together with the reports of meetings. The *Transactions*, in which the shorter papers and business reports have hitherto appeared, are now abolished and the matter appears in the Annals. The complete volumes of Annals now coincide with the calender year, and appear with a new typography and arrangement of pages.

The present edition of the Annals is 1,250. The Memoirs, issued in quarto form, are adapted to papers requiring large plates or tabulations. But one number has thus far been issued.

LIBRARY.

The Library numbers over 18,000 titles, and is especially rich in sets of the publications of American and Foreign Societies.

In this respect it is one of the most complete in this country. It is now shelved in room 507 Schermerhorn Hall at Columbia University, and is accessible to Members from 8 A.M. to 5 P.M.

MEETINGS.

The Academy at present meets at 12 West 31st St. Meetings are held every Monday at 8 P.M., from October to May, inclusive. The Academy meets in sections on successive Mondays in the following order: Astronomy and Physics: Biology (Zoölogy, Physiology, Botany); Geology and Mineralogy; Anthropology and Psychology. Other sections may be formed by a vote of the Council. Each of the sectional evenings is devoted mainly to scientific papers and discussions. All the meetings are open to the public and are announced, with the subjects of the papers to be read, in the bulletins of the Scientific Alliance of New York. The Academy also gives four Public Lectures each year, devoted to a popular discussion of recent advances in science.

SCOPE OF WORK.

Owing to the increased scientific activity in this city, expansion of the Academy's work is called for along two lines, publications, and grants for research. The Academy is endeavoring to increase its efficiency in the near future by securing a larger publication fund so that it will no longer be necessary to decline important scientific papers offered for publication, especially when accompanied by illustrations. A certain sum of money should also be available annually for lecture courses—such as the well-known lectures of the Royal Institution in London; and for grants for original research. Our scientific men give their results freely to the world with no thought of financial return in most cases, and should be aided in their work by Scientific Academies.

Persons desiring to join the Academy or to support its scientific work by subscription in either of the lines suggested above should address

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Teachers College, New York City.

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A

ANTHROPOLOGY.

In Charge of Franz Boas.

1. **Symbolism of the Arapaho Indians.** From the collections of the Jesup Expedition, American Museum of Natural History. Exhibited by Alfred L. Kroeber.
2. **Basketry Designs of California Indians.** From the collections of the C. P. Huntington Expedition, American Museum of Natural History. Exhibited by Roland B. Dixon.
3. **Designs of the Golds of the Amoor River.** From the collections of the Jesup North Pacific Expedition, American Museum of Natural History. Exhibited by Berthold Laufer.
4. **Archæology of the Coast of Southern British Columbia.** From the collections of the Jesup North Pacific Expedition, American Museum of Natural History. Exhibited by Harlan I. Smith.
5. **Implements of the Eskimo of Southampton Island.** From the collections of the American Museum of Natural History. Exhibited by George Comer.

B

ASTRONOMY.

In Charge of J. K. Rees.

1. **Photographs of Nebulæ made with the Crossley Reflector** Exhibited by the Lick Observatory, J. E. Keeler, Director; Mount Hamilton, California.
2. **Illustrations of Recent Investigations on Planets and Satellites.** Made at the Lowell Observatory, Flagstaff,

Arizona. Exhibited by A. E. Douglass, for Percival Lowell, Director.

3. **Results of Observations with the Zenith Telescope of the Flower Astronomical Observatory of the University of Pennsylvania.** Exhibited by C. L. Doolittle, Director.

4. *a.* **Photographs of Stars, Star-clusters, and Nebulæ by Isaac Roberts.**
   b. **Atlas Stellarum Variabilum, Series II, by J. G. Hagen, S. J.**
   c. **Other Recent Important Publications.** Exhibited by the Columbia University Library.

5. *a.* **Graphical Representation of the Variation of Latitude at New York City during the past seven years.**
   b. **Atlas Photographique de la Lune, publié par l'Observatoire de Paris; planches du quatrieme fascicule, 1899.**
   c. **Carte Photographique du Ciel, Observatoire de Paris.**
   d. **Recent publications by members of the Department of Astronomy.** Exhibited by the Columbia University Observatory, J. K. Rees, Director; New York City.

6. **Enlargement of the spectrum of α Cygni showing "enchanced lines."** Exhibited by Sir Norman Lockyer, Director Solar Physics Observatory, London.

C

BOTANY.

In Charge of D. T. MacDougal.

1. **Museum Methods Employed at the New York Botanical Garden.**
   a. Tube specimens.
   b. Exhibition microscopes.
   c. Photographs.
   d. Publications.

   e. System of labels.
   f. Book plate.

2. **Torrey Botanical Club Publications.**
   a. Bulletin of the Torrey Botanical Club.
   b. Memoirs.

3. **Recent Publications in Botany.**
   a. Books.
   b. Periodicals.

4. **Estimation of Growth by an Automatic Balance**; photographs. Exhibited by Professor ALEX. P. ANDERSON.

5. *a*. **Morphology of Darluca filum.**
   b. **Life-history of Erythronium Americanum.** Exhibited by Mr. F. H. BLODGETT.

6. **New and Interesting Mosses.** Exhibited by Mrs. E. G. BRITTON.

7. *a*. **Development of Embryo-sac of Delphinium exaltatum.**
   b. **Spore Formation of Lachnea scutellata.** Exhibited by Miss LOUISE B. DUNN.

8. *a*. **Soil and plant formations at the head of the Bay of Fundy.**
   b. **Demonstrations of Ecological Groups.** Exhibited by Professor W. F. GANONG.

9. *a*. **Mosses with a Hand Lens.**
   b. **Set of Pleurocarpous Mosses.** Exhibited by Dr. A. J. GROUT.

10. **Plates and demonstrations of Sporormia herculea E. & E.** Exhibited by DAVID GRIFFITHS.

11. **New Species of Scirpus from Georgia.** Exhibited by Mr. R. M. HARPER.

12. **Photomicrographs.** Exhibited by Professor BYRON D. HALSTED.

13. **Embryology of Viburnum.** Exhibited by Miss NELLIE HEWINS.

14. *a*. **Germination of the Cocoanut.**

b. **Substances Extracted from the Cocoanut.**
c. **Embryology of Micrampelis echinata.**
Exhibited by Mr. J. E. Kirkwood.

15. *a.* **Lycopodiums,** *b.* **Roots of Monotropa,** and *c.* **Demonstrations.** Exhibited by Professor F. E. Lloyd.

16. *a.* **Mycorhizas,** and *b.* **Etiolations.** Exhibited by Dr. D. T. MacDougal.

17. **New Species of Grasses from the Southern United States.** Exhibited by Mr. Geo. V. Nash.

18. **New Genera of Plants from Bolivia.** Exhibited by Professor H. H. Rusby.

19. **New Species of Senecios from the Rocky Mountains.** Exhibited by Dr. P. A. Rydberg.

20. **Rare and Interesting Mosses.** Exhibited by Mrs. A. M. Smith.

21. **Apparatus used in Study of Plant Physiology.**
a. Dynamometers for measuring the force of growth and curvatures.
b. Clinostat.
c. Influence of electricity upon plants.
d. Germinations.
e. Demonstrations.
Exhibited by Professor Geo. E. Stone.

22. **Influence of Cold upon the Growth of Sterigmatocystis.** Exhibited by Miss Ada Watterson.

23. **Mosses from the Klondike.** Exhibited by Mrs. E. G. Britton and Mr. R. S. Williams.

24. **Method of Determining Amount of Water Conduction in Plants.** Exhibited by Dr. C. C. Curtis.

D

CHEMISTRY.

In Charge of Charles E. Pellew.

1. **Specimens of Smokeless Powder.** Exhibited by Capt. H. C. Aspinwall.

2. **Artificial Indigo (German).** Exhibited by KUTTROFF, PICKHARDT & CO.
   - *a.* Specimen of Indigo J extra, made by the Badische Anilin and Soda Fabrik.
   - *b.* Woolen cloth dyed with Indigo J extra.

3. **Artificial Indigo (French).** Exhibited by Dr. HAROLD FRIES.
   - *a.* Specimen of artificial Indigo, made by the Societé Chimique des Usines du Rhône. Process of M. Monnet.
   - *b.* Samples dyed by artificial Indigo.

     For comparison, Samples of Natural Indigo. Exhibited by the CHEMICAL DEPARTMENT of Columbia University.

4. **Collection of recent Synthetic Perfumes of some Valuable Raw Materials for Perfumery.** Exhibited by Messrs. FRITZSCHE BROS. (Branch of Schimmel & Co.).
   - *a.* Synthetic Oil of Cassia, "Schimmel & Co." (Cinnamic Aldehyde). For comparison: Oil of Cassia, natural, and Oil of Cinnamon, Ceylon, natural.
   - *b.* Synthetic Oil of Hyacinth, "Schimmel & Co." Extract according to old formulas before this new synthetic was discovered. Extract in which this new synthetic is used.
   - *c.* Synthetic Oil of Jasmine, "Schimmel & Co." Extract according to old formulas. Extract in which new synthetic is used.
   - *d.* Synthetic Oil of Neroli, "Schimmel & Co." For comparison: Oil Neroli, Petale, natural, from Orange Flowers. Cologne made with natural oil. Cologne made with artificial oil.
   - *e.* Synthetic Oil of Ylang Ylang, "Schimmel & Co." Oil of Ylang Ylang, natural (Orchid Flowers) from Manila. Extract from natural oil. Extract with artificial oil.
   - *f.* Cumarin:

     For comparison . . . . Tonca beans.

g. Ionone: (The artificial perfume of Fresh Violets).
Violet Extract, old formula.
Violet Extract with new synthetic oil employed.

h. Vanillin:
For comparison.......................Vanilla beans.

i. Synthetic Oil of Lily of the Valley, "Schimmel & Co."

j. Synthetic Oil of Tuberose, "Schimmel & Co."

k. Samples: Musk, natural and artificial.
Pure Attar of Roses, Turkish and German.
Oil of Sandalwood, East Indian, Santalol being the chief constituent.
Musk caddies.
Musk wrappers.

5. **New Photographic Printing Process, using Phosphate of Silver Emulsion.** Invented by Johannes Meyer, M.D. Phosphate of silver prints on paper, linen and silk. Exhibited by Dr. ROBERT C. SCHÜPPHAUS.

6. **California Lepidolite and Lithium Carbonate manufactured from it.** Exhibited by Dr. WM. JAY SCHIEFFELIN.

7. **Pantasote, a Rubber Substitute.** Exhibited by Dr. WALDEMAR LEE.
Specimens illustrating its manufacture and use.

8. **Specimens of new Radio-active Elementary Substances from Pitch blende.** Exhibited by the CHEMICAL DEPARTMENT OF COLUMBIA UNIVERSITY and by Messrs. EIMER AND AMEND.

a. Radio-active Substance A.

b. Radio-active Substance B.

9. **Collection of New and Rare Alloys.** Ferro-silicium, Ferro-Titanium, Ferro-Chromium, etc., made in the electric furnace. Exhibited by Messrs. EIMER AND AMEND.

10. **Selected set of Strictly Chemically Pure Reagents,** as manufactured for and exhibited by Messrs. EIMER AND AMEND by Dr. C. A. F. Kahlbaum, Berlin. These reagents can be furnished with certain certificates of the

German Reichsanstalt proving purity for special chemical and physical work.

11. **New Chemical Charts.** Exhibited by Messrs. Eimer and Amend.
    - *a.* Official table of American Chemical Society, the elements with their atomic weights.
    - *b.* Chart of the periodic arrangement of the elements according to Professor Mendeljeff, corrected up to date, by Professor F. W. Clark.

12. **Collection of New Chemical Apparatus.** Exhibited by Messrs. Eimer and Amend.
    - *a.* Agate mill designed by Professor Maerker, especially constructed for Laboratories of Agriculture Stations; of use in reducing coarsely powdered fodder to fine state, and also useful for general laboratory work.
    - *b.* Gas pressure regulator, according to Professor Murrill; very convenient and simple form of laboratory pressure regulator, connected with a thermostat; temperature may be held constant within 0.1° C.
    - *c.* Analytical balance. New construction, with circular beam, reducing vibrations and increasing stability and rapidity of action.
    - *d.* New automatic cupel machine making 600 perfect cupels an hour.
    - *e.* Zeiss binocular microscope according to Greenough, made by Carl Zeiss (Eimer and Amend, Agents) for examining crystalline chemicals, minerals, etc.

E

ELECTRICITY.

In Charge of Geo. F. Sever.

1. **Reactance Conductor for investigating Cable Telephony.** Exhibited by M. I. Pupin.

2. **Farad-meter.** Made by E. V. Baillard. Exhibited by M. I. Pupin.
3. **Electrical Apparatus.** Exhibited by the General Electric Co.
   - *a.* Horizontal Edgewise Ammeter.
   - *b.* Horizontal Edgewise Voltmeter.
   - *c.* Standard Thomson Recording Wattmeter, 10 ampéres, 110 volts.
   - *d.* Lamp-testing Wattmeter—150 watts.
   - *e.* Pocket Ammeter, 25 ampéres.
   - *f.* Astatic Ammeter, 100 ampéres.
4. **Electrical Apparatus.** Exhibited by Queen & Co.
   - *a.* A Complete portable cable testing outfit.
   - *b.* The Queen-Le Chatelier pyrometer.
   - *c.* An 100,000-ohm box.
   - *d.* An Ayrton shunt box.
   - *e.* A new D'Arsonval galvanometer.
   - *f.* A portable photometer.
5. **Electrical Apparatus.** Exhibited by the Westinghouse Electric Mfg. Co.
   - *a.* Two-phase, Integrating Wattmeter.
   - *b.* Two-wire, Single-Phase, Integrating Wattmeter, with Series Transformer.
   - *c.* Two-wire, Single-Phase Integrating Wattmeter.
   - *d.* Three-wire, Single-Phase Integrating Wattmeter, with Series Transformer.
6. **Apparatus for Tracing Alternating Current Curves.** Exhibited by F. Townsend.

F

GEOLOGY AND GEOGRAPHY.

In Charge of Richard E. Dodge.

1. **Series of Maps Showing Progress in Topographic Work during 1899.** Exhibited by the United States Geological Survey, C. D. Walcott, Director, Washington, D. C.

a. New York State map showing progress for 1899.

b. Small printed index maps of Eastern United States.

c. Niagara, New York, on 2-mile scale and 5 maps of the same area on the 1-mile scale.

d. Albany, New York, and vicinity.

e. Lake Erie Shore Line.

f. Olean, New York, and vicinity.

g. Remsen and Wilmurt, New York, sheets.

h. Oswego, New York, and vicinity.

i. Finger Lakes, New York.

j. Indian Territory, sheets.

k. North Platte River, Nebraska.

l. Yosemite, California.

m. Pacific Coast, Oregon.

n. Hypsometric Map of the United States.

2. **Series of Maps and Publications Showing Progress in the Geological Surveys.** Exhibited by the UNITED STATES GEOLOGICAL SURVEY, C. D. Walcott, Director, Washington, D. C.

a. GEOLOGIC FOLIOS: Holyoke, Massachusetts; Big Trees California; Absaroka. Wyoming; Standingstone, Tennessee; Tacoma, Washington; Telluride, Colorado; Elmoro, Colorado.

WALL MAPS:

b. Tintic Mining region, Utah.

c. Absaroka Range, Wyoming.

d. Telluride Mining District, Colorado.

e. Mother Lode Mining District, California.

f. Tenmile Mining District, Colorado.

g. Trinidad Coal Field, Elmoro Folio, Colorado.

h. Estillville and Bristol Folios, Tennessee.

RECENT PUBLICATIONS:

i. 19th annual report of the Director of the Geological Survey.

j. Topographic Folio, showing physiographic types.

k. Monograph on the Geology of Narragansett Basin.
l. Monograph on the Crystal Falls Iron District of Michigan.
m. Monograph on the Illinois Glacial Lobe.

3. **Charts Illustrating the Geographical regions and the Distribution of the Mammalia During the Tertiary Period.** Used to illustrate the President's address before the Academy, February 26, 1900, entitled "The Geological and Faunal Relations of Europe during the Tertiary Period, and Theory of the Successive Invasions of the Ethiopian Fauna." Exhibited by Prof. HENRY F. OSBORN.

4. **Album of Recent Photographs of the Palisades of New Jersey.** J. R. Prince, photographer. Exhibited by the GEOLOGICAL SURVEY OF NEW JERSEY.

5. **Jersey City, Newark, Paterson, and Hackensack Sheets.** A part of the new series of the topographical maps of New Jersey. Exhibited by the GEOLOGICAL SURVEY OF NEW JERSEY.

6. **Annual Rainfall and Temperature Chart of Maryland.** Prepared and exhibited by the MARYLAND STATE WEATHER SERVICE.

7. **Series of Wall Charts Illustrating Meteorological and Geological Progress in Maryland.** Exhibited by the MARYLAND STATE WEATHER SERVICE, and the MARYLAND GEOLOGICAL SURVEY.

8. **Topographical and Geological Maps of Allegheny County, Maryland.** Exhibited by the MARYLAND GEOLOGICAL SURVEY.

9. **Publications of the Maryland Geological Survey and Maryland Weather Service.** Annual reports and folio of maps.

10. **Bartholomew's Physical Atlas, Volume III.: Meteorology.** Exhibited by the DEPARTMENT OF GEOGRAPHY, TEACHERS COLLEGE, Columbia University.

11. **Series of Colored Lantern Slides, Illustrating Physical**

and Political Features of the Different Continents. Prepared by Dickinson and Andrews, London, England, and exhibited by the DEPARTMENT OF GEOGRAPHY, TEACHERS COLLEGE, Columbia University.

12. **Orographical Outline Maps of the Continents and Divisions Thereof.** Prepared by Dickinson and Andrews, London, England, and exhibited by the DEPARTMENT OF GEOGRAPHY, TEACHERS COLLEGE, Columbia University.

13. **Model of Cape Cod, Massachusetts.** Prepared by Professor V. F. Marsters, Indiana University, Bloomington, Indiana, and exhibited by the DEPARTMENT OF GEOGRAPHY, TEACHERS COLLEGE, Columbia University.

14. **Specimens Illustrating the Rocks of the Yellowstone National Park.** Collected and exhibited by EDMUND OTIS HOVEY, American Museum of Natural History.

15. **Monograph XXXII, Part 2, United States Geological Survey:** Geology of the United States National Park. Exhibited by EDMUND OTIS HOVEY, American Museum of Natural History.

16. **Geological Atlas of the United States, Yellowstone National Park Folio.** Exhibited by EDMUND OTIS HOVEY, American Museum of Natural History.

17. **Copper Ore and Associated Minerals, Last Chance Mine, Colorado Canyon, Col.** Exhibited by HEINRICH RIES, Cornell University.

18. **Suite of Clays and Shales from Michigan.** Exhibited by HEINRICH RIES, Cornell University.

19. **Series of Specimens Illustrating the Physical Properties of Clay.** Exhibited by HEINRICH RIES, Cornell University.

20. **Some New and Interesting Clays from Alabama.** Exhibited by HEINRICH RIES, Cornell University.

21. **Series of Ores and Associated Rocks from the Mother Lode**

in California. Exhibited by HEINRICH RIES, Cornell University.

22. **Dolomite Crystals and Pilinite, New Almaden, Cal.** Exhibited by HEINRICH RIES, Cornell University.

23. **Telluride Gold Ores from Colorado.** Specimens from the Cripple Creek district and from the Independence and the Hallett and Hamburg Mines at Victor. Exhibited by J. T. HALLETT.

24. **Quicksilver Ore (Cinnabar) and associated rocks and minerals.** Collected by W. P. Jenney, February, 1900, in Brewster County, southwestern Texas. Exhibited by J. F. KEMP.

25. **Serpentine-Verdalite, from Easton, Penna.** The specimens were obtained at the recently opened quarries of the Verdalite Company at Easton and were cut and polished there. The rocks were described by Professor F. B. Peck before the Academy. January 15, 1900. Exhibited by JAMES W. FOX, Esq.

26. **Nepheline-Syenites and related rocks from Magnet Cove, Arkansas.** These rocks were described by Dr. H. S. Washington before the Academy, on February 19, 1900. Exhibited by H. S. WASHINGTON.

G

METALLURGY.

IN CHARGE OF PROFESSOR HENRY M. HOWE.

1. **Ductility of Steel.**
    1. One-inch square bar knotted cold.
    2. Seven-inch square steel bar bent double cold.
    2.1 "Barked" Wrought Iron.
2. **Formation of Contraction Cavities in Suddenly-Cooled Solids.**

3. Paraffine Ingot cooled slowly.
4. Paraffine Ingot cooled quickly.
5. Steel Ingot cooled quickly.
5.1 Aluminum Ingot cooled quickly.

3. Evolution of Gas by Metals During Solidification.

6. Over-poled Copper.
7. Spitting of Silver.
8. Steel Casting with Blow-holes.
9. Steel Ingot with Blow-holes.
10. Steel Ingot with Blow-holes.
11. Steel Ingot, Blow-holes prevented by adding aluminum.

4. Metallography of Steel.

a. Crystalline Form of the Constituents of Steel.

12. Crystalline form of Ferrite (pure iron).
13. Crystalline form of Ferrite (pure iron).
14. Crystalline form of Cementite (Fe_3C).
15. Crystalline form of Cementite.
16. Crystalline form of Graphite.

b. Micrographs.

17. Ferrite.
18. Pearlite (eutectic, ferrite and cementite interstratified).
19. Pearlite with cementite.
20. Martensite.
21. Microstructure of Steel as effected by thermal treatment.
22. Microscope with Section of Pearlite.

c. Influence of the mode of rupture and of thermal treatment on the structure of iron and steel.

23. Fibrous and crystalline Fracture in the same Bar.
24. Coarse and fine Fracture in the same Bar.
25. Series of fractures Representing different Temperatures.
26. Coarse and fine Fractures in the same Face.
27. Coarse and fine Fractures in the same Face.
28. Coarse and fine Fractures in the same Face.
29. Coarse and fine Fractures in the same Face.

29.1 Chilled Cast-iron.
29.2 Coarse Structure in Sheet steel.
29.3 Influence of Temperature on the Hardening Power of Steel.

5. New Special or Alloy Steels.

30. 25% Nickel Steel.
31. Manganese Steel quenched from 1050° C. in a freezing mixture.
32. Manganese Steel quenched from 1050° C. in molten lead.
33. Manganse Steel cooled slowly.
34. Tungsten Steel.
35. Heavy Chip cut from Steel Forging by Tungsten Steel Tool.
36. Molybdenum Steel.
37. Chrome Steel.
38. Gruson Chilled Cast Iron Armor.
39. Harvey Nickel Steel Armor.
40. Oxide Colors for tempering steel.

6. Non-Ferrous Metals.

42. Metallic Nickel from Carbonyl.
42.1 Nickel made by the Mond process.
42.2 Nickel Electro deposited.
43. Rosette Copper.
44. Hübnerite, Tungsten Ore, 68 to 72 per cent. WO_3.
45. Hübnerite, Tungsten Ore concentrated first grade 76, to 70 per cent. WO_3.
46. Ferro-Tungsten, 37 per cent. W.
47. Metallic-Tungsten, 95 to 97 per cent.
48. Ferro-Molybdenum 50 per cent. Mo.
49. Metallic Molybdenum 95 to 99 per cent.
50. Ferro-Boron, free from carbon, 25 per cent. B.
51. Metallic Manganese, free from carbon.
52. Ferro-Chromium 66 per cent.

53. Metallic Chromium, free from carbon; over 99 per cent. Cr.
54. Ferro-Titanium, 20 per cent. Ti.
55. Ferro-Titanium, 10 per cent. free from carbon.
55.1 Metallic Tellurium.
56. Antimony from Japan.
57. Metallic Zinc and its ores.
58. Ores of Aluminum, cryolite.
59. Ores of Aluminum, Bauxite.
60. Anhydrous Alumina.
61. Ingot of Aluminum.
61.1 Aluminum foil, $\frac{1}{75000}$ of an inch thick.
62. Carborundum Crystals from Electric Furnace.

7. Refractory Materials.

63. Clay Brick.
64. Silica Brick for Extreme Temperatures.
65. Magnesia Brick to Resist Basic Slags.
66. Chromic Neutral Brick, Resisting both Acid and Basic Slags.

8. Models of Metallurgical Apparatus.

67. Bessemer Converter.
68. Siemen's Regenerative Gas Furnace.
69. Iron Blast Furnace.
70. Hot-blast Stove for heating blast for iron blast furnace.

9. Pyrometry.

71. Le Chatelier thermo-electric pyrometer.

10. Lecture Diagrams.

72. Triaxial diagram of the isotekes of the lime-alumina silicates.
73. Duquesne Blast Furnaces of the Carnegie Steel Company.
74. Duquesne Blast Furnaces of the Carnegie Steel Company.
75. Flame of the Bessemer Process.
76. Flame of the Bessemer Process.

77. Flame of the Bessemer Process.
78. Flame of the Bessemer Process.
79. Flame of the Bessemer Process.
80. Flame of the Bessemer Process.
81. Wellman 50-ton tipping open-hearth furnace.
82. Herreshoff Copper Smelting Cupola Furnace.

H

MINERALOGY.

IN CHARGE OF L. McI. LUQUER.

1. **Minerals from the Collections of the American Museum of Natural History.** Exhibited by L. P. GRATACAP.

1. Native Gold, in Limonite, San Juan, Colorado.
2. Tellurium (group of crystals), Boulder Co., Colorado.
3. Coloradoite, Boulder Co., Colorado.
4. Lionite, Boulder Co., Colorado.
5. Nagyagite, Boulder Co., Colorado.
6. Leadhillite, Cerussite, concentric upon a nucleus of Galenite, Lehmi Co., Idaho. (The above minerals are part of the Theodore Berdell gift to the American Museum of Natural History.)
7. Bixbyite, near Simpson, Utah.
8. Limonite (altered Pyrite), Xaaga, near ruins of Mitla, 600 feet elevation, Oaxaca, Mexico.
9. Martite, Twin Peaks, Utah.
10. Wood Opal, Douglass Co., Washington.
11. Willemite (red), Franklin, N. J.
12. Willemite (enclosing needles of Franklinite?), Franklin, N. J.
13. Epidote, Ouray Co., Cal.
14. Melanotekite, New Mexico.
15. Calamine (yellow), Lone Elm near Joplin, Mo.
16. Spodumene, Black Hills, Wyoming.

17. Mixite, Utah.
18. Clinoclasite, Utah.
19. Pyromorphite, Cornwall, England.
20. Barite, Mowbray, Cumberland, England.
21. Barite, Frizington, Cumberland, England.
22. Anhydrite, Bleiberg, Carinthia.
23. Celestite, Cianciana, Sicily.
24. Selenite (with inclusions), Cianciana, Sicily.
25. Smithsonite (stalactitic), Laurium, Greece.
26. Parisite, Ravelli Co., Montana.
27. Calcite group, Bisbee, Arizona.
28. Calcite group, Joplin, Mo.
29. Calcite, Bisbee, Arizona.
30. Calcite (two groups, sand saturated), Washington, Dakota.
31. Calcite (four specimens), Wind Cave, Black Hills, Wyoming.
32. Aragonite (large group), Cianciana, Sicily.
33. Linarite, Cumberland, England.
34. Fluorite, Cumberland, England.
35. Hematite (crystals on volcanic ash), Santa Fé, New Mexico.
36. Hardystonite (dark) with Rhodonite, Franklin, N. J.
37. Calcite and Aragonite, Wind Cave, Black Hills, Wyoming.
38. Wurtzilite, Uintah Mts., Wasatch Co., Utah.

2. **Minerals and Meteorites from Various Localities.** Exhibited by the FOOTE MINERAL COMPANY; Philadelphia and Paris.

MINERALS.

1. Diamond crystal, 4⅓ cts., North Carolina.
2. Sulphur groups and various small crystals, Sicily.
3. Molybdenites, Ontario.
4. Marcasite Disks, Illinois.
5. Embolite, Broken Hill, N. S. W.

6. Iodyrites, crystals and massive, Broken Hill, N. S. W.
7. Pink Fluorites, cleavages, Arizona.
8. Amethysts, Virginia.
9. Opalized Wood, polished, Idaho.
10. Opals, precious, Queensland.
11. Opals, pseudo cryst., White Cliffs, N. S. W.
12. Opals, polished, White Cliffs, N. S. W.
13. Opals, in Petrified Wood, White Cliffs, N. S. W.
14. Hematites, Elba.
15. "Papierspaths" Calcite, New Mexico.
16. Cerussites, Broken Hill, N. S. W.
17. Cerussite, Tasmania.
18. Aurichalcites, New Mexico.
19. Various Amazon stone groups, Colorado.
20. Emerald, North Carolina.
21. Phacolite, Victoria.
22. Turquois, New Mexico.
23. Colemanite, California.
24. Anglesites, coating twinned Cerussite, Broken Hill, N. S. W.
25. Crocoites and various crystals, Tasmania.
26. Ambers, containing insects, Baltic.
27. Clinohedrite, Franklin.
28. Glaucochroite, Franklin.
29. Hancockite, Franklin.
30. Hardystonite crystals, Franklin.
31. Leucophœnicite, Franklin.
32. Nasonite, Franklin.
33. Roeblingite, Franklin.

METEORITES.

34. Sacramento Mts., 4650 grams.
35. Tombigbee River, showing Schreibersite, 2960 grams.
36. Joe Wright Mt., 128 grams.
37. Butler, 75.5 grams.
38. Trenton, 26 grams.
39. Hammond, 20 grams.

3. **Minerals.** Exhibited by ROY HOPPING.
    1. Crocoite, from the silver-lead mines of Tasmania.
    2. Pyrite discs, from the soft carbonaceous coal shale of Randolph Co., Ill.
    3. Kidney Ore, from Cumberland, England.
    4. Green Zoisite, from Connecticut.
    5. Strontianite, from Westphalia, Germany.
    6. Fuggerite, new species, from Tyrol, Austria.

4. **Minerals.** Exhibited by GEO. L. ENGLISH & Co.
    1. Fluorite, emerald green, Westmoreland, N. H.
    2. Fluorite, pink octahedrons, Switzerland.
    3. Hematite, "Iron Rose," Switzerland.
    4. Brookite, extra large crystals, Switzerland.
    5. Smoky Quartz crystals, Switzerland.
    6. Twisted Quartz crystals, Switzerland.
    7. Rutilated Quartz crystals, Switzerland.
    8. Quartz Crystals enclosing Actinolite, Switzerland.
    9. Quartz Crystals rendered black by enclosure of needles of Tourmaline, Montana.
    10. Amethyst tipping Quartz, enclosing Tourmaline, Montana.
    11. Amethyst crystals in parallel position, Montana.
    12. Crystallized Argentite, Colorado.
    13. Epidote crystals, Colorado.
    14. Carnotite, a new uranium-potassium vanadate, Colorado.
    15. Hardystonite, a new mineral, Franklin Furnace, N. J.
    16. Graftonite, a new mineral, Grafton, N. H.
    17. Labradorite, rare colors, Labrador.
    18. Lepidolite, Haddam Neck, Conn.
    19. Silicious Calcite crystals, "Fontainebleau Limestone," S. Dak.

5. **Tellurium Minerals from American Localities.** Exhibited by ALBERT H. CHESTER, Rutgers College.
    1. Native Tellurium, John Jay mine, Boulder County, Colorado.

2. Native Tellurium (dendritic), John Jay mine; Boulder County, Colorado.
3. Native Tellurium, Mountain Lion mine; Magnolia, Colorado.
4. Native Tellurium, Keystone mine; Magnolia, Colorado.
5. Native Tellurium, Rebecca mine; Magnolia, Colorado.
6. Native Tellurium, Smuggler mine; Balarat, Colorado.
7. Native Tellurium, Cold Spring mine; Gold Hill, Colorado.
8. Lionite, Mountain Lion mine; Magnolia, Colorado.
9. Hessite, Slide mine; Gold Hill, Colorado.
10. Hessite, American mine; Sunshine, Colorado.
11. Hessite, St. Joe mine; Gold Hill, Colorado.
12. Hessite and Gold, Colorado.
13. Petzite, Ellen mine; Springdale, Colorado.
14. Petzite, Grand Central mine; Springdale, Colorado.
15. Petzite, American mine; Sunshine, Colorado.
16. Petzite and Gold, American mine; Sunshine, Colorado.
17. Petzite and Gold, Slide mine; Gold Hill, Colorado.
18. Petzite and Gold, Little Alice mine; Gold Hill, Colorado.
19. Petzite, Cold Spring mine; Gold Hill, Colorado.
20. Petzite, Corning Tunnel; Gold Hill, Colorado.
21. Petzite, Red Cloud mine; Gold Hill, Colorado.
22. Petzite, Bassick mine; Custer Co., Colorado.
23. Altaite, John Jay mine; Boulder Co., Colorado.
24. Altaite, Slide mine; Gold Hill, Colorado.
25. Altaite and Sylvanite, Smuggler mine; Balarat, Colorado.
26. Altaite, Red Cloud mine; Gold Hill, Colorado.
27. Altaite, King's Mt., North Carolina.
28. Altaite and Gold, King's Mt., North Carolina.
29. Coloradoite, Keystone mine; Magnolia, Colorado.
30. Coloradoite and Mercury, Keystone mine; Magnolia, Colorado.
31. Coloradoite, Smuggler mine; Balarat, Colorado.

32. Coloradoite and Tellurite, Smuggler mine; Balarat, Colorado.
33. Coloradoite and Mercury, Smuggler mine; Balarat, Colorado.
34. Sylvanite, American and Nil Desperandum mines; Sunshine, Colorado.
35. Sylvanite and Fluorite, Melvina mine; Salina, Colorado.
36. Sylvanite, Ingraham mine; Gold Hill, Colorado.
37. Sylvanite, Smuggler mine; Balarat, Colorado.
38. Sylvanite and Fluorite, Independence mine; Cripple Creek, Colorado.
39. Calaverite, Mountain Lion mine; Magnolia, Colorado.
40. Krennerite, Independence mine; Cripple Creek, Colorado.
41. Tellurite, John Jay mine; Boulder Co., Colorado.
42. Tellurite, Grand View mine; Sunshine Co., Colorado.
43. Magnolite, Keystone mine; Magnolia Co., Colorado.
44. Ferrotellurite, Keystone mine; Magnolia Co., Colorado.
45. Cerargyrite and Gold, altered from Petzite, American mine; Sunshine, Colorado.
46. Cerargyrite and Gold, altered from Petzite, Slide mine; Gold Hill, Colorado.
47. Gold, pseud. after Sylvanite, Grand View mine; Sunshine, Colorado.
48. Gold, pseud. after Sylvanite, Cripple Creek, Colorado.
49. Telaspyrine, American mine; Sunshine, Colorado.
50. Gold, roasted Calaverite, Keystone Mine; Magnolia, Colorado.
51. Gold, roasted Sylvanite, Smuggler Mine; Balarat, Colorado.

6. New Apparatus Employed in the Examination of Minerals. Exhibited by the "EGLESTON MINERALOGICAL MUSEUM," of Columbia University.

1. Fuess Student Microscope, latest model.
2. Stöber's attachment to convert the Fuess Goniometer into a Two-circle Goniometer.

3. Student Application Goniometer, made at a cost of 50 cts.
4. Models made by Crystal Cutting Apparatus of Goldschmidt. *Zeit. f. Kryst.*, Vol. 31, p. 223.

From "Introductory Collection to the Study of Mineralogy."

5. Models illustrating Symmetry.
6. Specimens illustrating Streak.

7. Minerals. Exhibited by the "EGLESTON MINERALOGICAL MUSEUM," of Columbia University.

Nos. 1 to 12 are from the recently acquired Egleston collection.

1. Arseniosiderite, Romanèche, France.
2. Vivianite in shells, Crimea.
3. Titanite (Greenovite), Piedmont.
4. Helvite, Schwarzenberg.
5. Vesuvianite, with Essonite, Ala, Piedmont.
6. Zircon, Urals.
7. Zircon, Renfrew.
8. Zoisite, with Chalcopyrite and Sphalerite, Ducktown, Tenn.
9. Petalite (Castorite), Elba.
10. Cassiterite, Bohemia.
11. Cassiterite, Morbihan, France.
12. Chalcopyrite [(114) and $(4\bar{4}1)$] with quartz, Ellenville, N. Y.
13. Leucophœnicite (new mineral), Franklin Furnace, N. J.
14. Hardystonite (new mineral) with Franklinite, Franklin Furnace, N. J.
15. Nasonite (new mineral) with Axinite and Garnet, Franklin Furnace, N. J.
16. Carnotite (new mineral), Paradox Valley, Cal.
17. Graphite, near Mt. Freedom, N. J.
18. Reddingite, Branchville, Conn.
19. Hureaulite, Branchville, Conn.
20. Boleite and Anglesite, Boleo, Lower Calif.
21. Azurite (needle crystals), Zacatecas.

22. Chalcopyrite (large crystals), Zacatecas.
23. Arsenopyrite (needles) on Chalcopyrite, Zacatecas.
24. Copper (leaf) on Datolite, Lake Superior.
25. Struvite (hemimorphic crystals), Hamburg.
26. Pyrite (dodecahedral) on Smoky Quartz, Thunder Bay, U. S.
27. Gold in conglomerate in quartz vein, Dutch Flat, Calif.
28. Whitneyite (fragment of only lump found), Lake Superior.
29. Sapphire (twinned), Cashmere.
30. Apophyllite (with flat pyramid), Iceland.
31. Anglesite, with core of Galenite, Monarch, Colo.
32. Quartz (Phantom) containing Chlorite, Chamounix.
33. Sphalerite (tetrahedral) and Chalcopyrite Ouray, Colo.,
34. Artificial minerals.
35. Alloys of gold made by R. Pearce.

5. **Mohawkite,** a new Arsenide of Copper and Nickel, from the Mohawk Mine, Keweenaw Point, $(CuNi)_4As$. Exhibited by J. F. Kemp.

J

PALEONTOLOGY.

In Charge of Gilbert van Ingen.

I. **Skeletons and Restorations of Fossil Vertebrates Chiefly from the Tertiary Rocks of Western America.** Exhibited by the Department of Vertebrate Paleontology, of the American Museum of Natural History. Henry F. Osborn, Curator.

1. **Mounted Skeletons of Two Primitive Carnivorous Mammals (Creodonts) from the Eocene Badlands of Wyoming.**
    a. *Oxyæna*, from the Lower Eocene Badlands of the Big Horn Basin.

b. *Patriofelis*, from the Middle Eocene Badlands of the Bridger Basin.

2. **New or Little Known Fossil Mammals from the Oligocene and Miocene Badlands of Colorado.** Collected by American Museum Expedition of 1898, W. D. Matthew in charge. Skeletons, parts of skeletons and skulls of primitive ruminants, camels, horses, sabre-tooth tigers, civet-foxes, et cetera.

3. **Fossil Mammals from the Miocene and Pleistocene Badlands of Texas.** Collected by American Museum Expedition of 1899, J. W. Gidley in charge.

a. Primitive Mastodon, skull and hind-limb bones. From Upper Miocene strata.

b. Mammoth (*Elephas primigenius*), jaw, fore-limb bones, vertebræ and ribs. From Pleistocene strata.

c. Fossil Horse (*Equus occidentalis*), complete skeleton and four skulls. From Pleistocene strata.

4. **Restorations of Fossil Vertebrates by Charles Knight.** From skeletons in American Museum of Natural History.

No. 25. *Great Marine Lizard or Mosasaur* (*Tylosaurus*), of the Cretaceous Period. From the complete skeleton which is nearly thirty feet long.

No. 26. *The Irish Elk* (*Megaceros hibernicus*) of the Pleistocene Period.

II. **Series of Photographs, 25 in Number Illustrating the Occurrence of the Mastodon Recently Discovered at Newburg, N. Y.** Exhibited by W. G. LEVISON.

K

PHYSICS AND PHOTOGRAPHY.

IN CHARGE OF WILLIAM HALLOCK.

1. **Apparatus and Records for Determination of Stresses in Railway Rails.** Exhibited by P. H. DUDLEY.

1. Comparison of curves of the stresses set up in 80-lb. rails, and waves in the roadbed under the wheel loads of the Empire State Express, for December 23 and 30, 1899, speed 44 miles per hour.
2. Similar curves for the same train on 100-lb. rails, June 28 and July 21, 1898, speed 19 miles per hour.
3, 4 and 5. Tabulations of stresses from which the above curves were obtained.
6 and 7. Photographs of locomotives passing over the stremmatograph, showing the position of counterweights and volume of exhaust steam.
8 and 9. Photographs of entire trains passing over the stremmatograph.
10. Photograph of stremmatograph slide, showing the recorded strains of several locomotives.

2. **Photographs in Color, by the Grating Principle.**
3. **New Form of Pseudoscope.**
4. **Kinetoscope Projections of the Motion of a Wave in Various Mirrors, and after Repeated Reflection.** Nos. 2 to 4, exhibited by Prof. R. W. WOOD; University of Wisconsin.
5. **Achromatic Quarter Wave-length Plate.** Exhibited by Prof. D. B. BRACE; University of Nebraska.
6. **A Sound Wave Anemometer.** Exhibited by BERGEN DAVIS; Columbia University.
7. **A Series of Prints Illustrating Manly's Ozotype Process of Pigment Printing.** Prepared and exhibited by Prof. T. W. EDMONDSON; New York University.
8. **Series of Diffraction Photographs.** Exhibited by Prof. W. S. FRANKLIN; Lehigh University.
9. **A Variable Potential Rheostat.** Exhibited by Prof. W. M. STINE; Swarthmore College.
10. **Photographs of Manometric Flames.** Exhibited by Professors E. L. NICHOLS and E. MERRITT; Cornell University.

11. **Enlargements of Photographs of the Electric Arc, with and without Metals.** Exhibited by A. L. Foley; Cornell University.
12. **Enlargements of Photographic Traces made with the Hotchkiss Galvanometer.** Exhibited by Prof. E. Merritt; Cornell University.
13. **Photographs of Traces of Gyroscopic Pendulum.** Exhibited by Prof. E. Merritt; Cornell University.
14. **Thin Metallic Film High Resistances.** Exhibited by A. C. Longden; Columbia University.
15. **Newton's Rings in Thin Selenium Films.** Exhibited by A. C. Longden; Columbia University.
16. **Induction Apparatus, and X-ray Tube.** Exhibited by E. L. Knott & Co.; Boston.
17. **Photograph of Manometric Flame Showing the Octave in the Forced Vibration of a Tuning Fork.** Exhibited by W. Hallock; Columbia University.
18. **Modified Form of the Pupin Interrupter.** Exhibited by W. Hallock; Columbia University.
19. **Gelatine Half-wave-length Zone Plate.** Exhibited by Prof. R. W. Wood; University of Wisconsin.

L

PSYCHOLOGY.

In Charge of Edw. L. Thorndike.

1. **Preliminary Apparatus for Recording the Vibrations of the Human Voice.** Exhibited by Professor C. H. Judd; New York University School of Pedagogy.

2(*a*). **Apparatus for Recording the Steadiness, Accuracy and rapidity of Very Small Movements.** (*b*) **Apparatus for Recording the Force of a Blow.** Exhibited by Dr. R. S. Woodworth; New York University Medical School.

3. **New Methods for Demonstrating Psychological Phenomena with the Stereopticon.** Exhibited by Professor J. McK. CATTELL; Columbia University.
4. **Apparatus for Studying the Diffusion of the Motor Impulse.** Exhibited by CLARK NISSLER; Columbia University.
5. **A Graded Series of Areas for Use in Studies of Discrimination and Practice.** Exhibited by Dr. EDW. L. THORNDIKE; Teachers College, Columbia University.

M

ZOÖLOGY.

IN CHARGE OF CHARLES L. BRISTOL.

1. **Anatomical Preparations.** From the Morphological Museum of Princeton University.
   Exhibited by Professor C. F. W. McCLURE.
2. **Osteological Specimens.** Showing improved methods of preparation. Exhibited by S. H. CHUBB.
3. **Map of the New York Zoölogical Park.** Showing improvements, so far as completed.
   Exhibited by W. T. HORNADAY.
4. **Photographs of the New York Zoölogical Park.** A collection showing the buildings and animals.
   Exhibited by W. T. HORNADAY.
5. **The Young of the Hag-fish, Bdellostoma stouti.** A unique specimen of the newly-hatched young of this Hag-fish secured during the past summer near Monterey, California. Exhibited by BASHFORD DEAN.
6. **Eggs of the Atlantic Hag-fish, Myxine glutinosa.** Until the present year, the specimens here exhibited were unique. Collected from deep sea fishers (St. George's Bank, Newfoundland), by Prof. A. E. Verrill, of Yale

University. Exhibited with them are the Eggs of the Pacific Hag-Fish, *Bdellostoma stouti.*
Exhibited by Bashford Dean.

7. **The Pearly Nautilus, Nautilus pompilius.** Collected in the Solomon Islands, by Dr. Arthur Willey.
Exhibited by Edmund B. Wilson.

8. **Earthworm with gills, Alma nilotica, from the Nile Valley.** Exhibited by Edmund B. Wilson.

9. **Born wax-plate model of larval Ceratodus.**
Exhibited by Bashford Dean and J. H. McGregor.

10. **Born wax-plate model of the head of a Seven Day-embryo Chick.** Exhibited by W. S. Wallace.

11. **Fish and Preparations illustrating a Brook-Trout epidemic due to Sporozoa** (*nov. gen. et. nov. sp.*).
Exhibited by G. N. Calkins.

12. **Preparation showing Ciliated Cells with Basal Bodies and Internal Fibrillæ.**
Exhibited by E. U. Van Harlingen.

13. **Photographs illustrating the Natural History of Nova Scotia.** Exhibited by C. W. Beebe.

14. **Illustrations of Cave Animals; from Kentucky and Indiana Caverns.** Exhibited by R. Ellsworth Call.

15. **Preparations of the Heads of Harmless and Poisonous Snakes.** Exhibited by Raymond Lee Ditmars.
    1. Heads of non-venomous snakes, showing the swallowing teeth, and representative charateristics.
        - *a.* Heads of Cuban Boa (Xiphisoma) mounted with open mouth, to show formation and distribution of teeth.
        - *b.* Head of typical "harmless" snake (water snake) showing position of shields.
        - *c.* Skeleton head of Boa (Boa constrictor), showing the dentition of a non-venomous snake.
    2. Heads of venomous snakes, showing the poison apparatus.

- *d.* Head of Rattlesnake (Crotalus adamanteus) showing the poison fangs partially raised.
- *e.* Head of Rattlesnake (Crotalus terrificus) showing the fangs raised as in the act of biting.
- *f.* Head of Rattlesnake (Crotalus adamanteus var. atrox). The fangs are fully raised.
- *g.* Head of Water Moccasin (Ancistrodon piscivorus). In this example the fangs rest against the roof of the mouth.
- *h.* Skeleton head of Rattlesnake (Crotalus adamanteus), showing the dentition.
- *i.* Chart, showing dissection of the head of a poisonous snake. The gland secreting the venom is seen behind the eye.
- *j.* Snake venom. Dried and in liquid form.
- *k.* Fang of poisonous snake under magnifying glass.

16. **Developmental Stages of Some Australian Animals.**

Exhibited by BASHFORD DEAN.

1. Specimens illustrating Development of Spiny Ant-Eater (Echidua).
2. Specimens illustrating Development of Various Australian Marsupials.
3. Large Embryos of Ceratodus.

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THE CRUSTACEA OF THE BERMUDA ISLANDS

WITH NOTES ON THE COLLECTIONS MADE BY THE NEW YORK UNIVERSITY EXPEDITIONS IN 1897 AND 1898.

W. M. RANKIN.

(Read May 8, 1899.)

[Plate XVII.]

FOR a few weeks during each of the summers of 1897 and 1898, a party sent out by the New York University was in the Bermudas investigating the fauna and the general character of the islands, with a view to the desirability of establishing there a permanent biological station. Among the various collections gathered was a considerable number of Crustacea, which have been in my hands for identification and study.

Hitherto the most complete list of the Bermuda Crustacea has been that of Heilprin, who, in 1888, conducted to the islands a party from the Philadelphia Academy of Natural Sciences. Some of the results of this expedition were published in the "Proceedings of the Philadelphia Academy" of that year, and in book form—"The Bermuda Islands"—the following year. Professor Heilprin enumerated 27 species, all but four of which have been collected by the N. Y. University expedition, but which now puts on record in the following list 43 species, 16 more than Heilprin collected.

Besides Heilprin's list there are several other recorded collections from the Bermudas, and it has been my purpose in the present paper to gather together all these reports and to compile, along with the notes on the species of this expedition, a complete list of the hitherto recorded Crustacea of the Bermuda islands.

BIBLIOGRAPHY.

The publications, which include special collections of Crustacea from the Bermudas, are as follows:

J. M. Jones—"The Naturalist in Bermuda," London, 1859.

A. Heilprin—"The Bermuda Islands," Philadelphia, 1889.

A. E. Ortmann—"Decapoden und Schizopoden der Plankton-Expedition," 1893.

The following "Reports of the Challenger Expedition":

"The Brachyura," **Miers**; "The Anomura," **Henderson**; "The Macrura," **Spence Bate**; "The Stomatopoda," **Brooks**; "The Phyllocarida," **Sars.**

In addition to these published lists I have, through the kindness of Miss Rathbun, of the U. S. National Museum, received a list of the Crustacea collected by Dr. G. Brown Goode at the Bermudas in '76 and '77, and now in the National Museum. I have also seen several species in the American Museum of Natural History in New York, which were collected by Professor Whitfield.

MATERIAL STUDIED FOR THIS PAPER.

In the present paper I have noted for each species, so far as I have been able to determine, its recorded observance by the authorities quoted above, and have likewise indicated those found in the Goode and Whitfield collections. The results of this compilation give a total of 61 species.

The Amphipoda and Isopoda, several species of which were collected, still await identification.

Doubtless this total represents very imperfectly the crustacean life of the Bermudas. During the two short seasons spent on the islands by the expedition no particular attention was given to the Crustacea above other forms of marine life; and the fact that 18 species recorded by other investigators were not discovered by this expedition, argues for the existence of many more, as yet unrecorded.

The field of research was limited, being mostly confined to Castle Harbor, at Walsingham, in '97, and to Bailey's Bay on the north shore, in '98, at which two localities the temporary laboratory was situated. The most of the littoral forms were found in the vicinity of these two places. Tonging for coral in Castle Harbor, at a depth of a few feet, gave some of the rock-living forms, as *Alpheus*. Expeditions to Castle, Cooper, and St. David islands, increased the number, especially in land and rock crabs (*Gecarcinus* and *Grapsus*). In 1897 an excellent opportunity was afforded the expedition of learning something of the bottom at six fathoms depth, through the courtesy of Lieut. Gubbins, in charge of the government dredger "St. Albans," at work in the channel at St. George; from the material thus gathered several species of *Alpheus* were procured. In 1898 some attempt at hand dredging at the Flatts and in Harrington Sound was made. The securing of a new species of *Nika*, a genus hitherto unknown from this region, and the *Nebalia* of the Challenger Expedition, proves that many interesting forms may be found by an extension of the work on these lines.

CHARACTERISTICS OF THE BERMUDA CRUSTACEAN FAUNA.

The physical conditions of the Bermudas: warm, shallow waters, a coral shore, largely rocky, but with stretches of sandy beach, would naturally lead us to expect a similarity in their crustacean fauna to that of the West Indies and the adjacent shores of Florida; and such, in fact, we find to be the case. The land-crabs, *Gecarcinus*, find dry exposed hillsides suitable for their burrows; the mangrove swamps hide the bright colored *Goniopsis*; on the spray-washed cliffs the rock-crab, *Grapsus*, climbs; the great variety of littoral crabs find shelter under the stones of the beaches; and masses of Sargassum conceal the *Nautilograpsus*, which, with *Leander natator*, and perhaps others, have found their way to the islands in the floating weed. In the tide-pools may be found the swimming crabs, *Callinectes* and *Acheloüs*, and the hosts of the agile shrimp, *Leander affinis*; while the coral is tunneled by, and gives shelter to, the *Alpheus* and *Gonodactylus*.

All these characters of the Bermudan shores must be familiar to one who has visited the West Indies; so it is not surprising to find that out of a total of 61 species in this list all but five have already been reported from the neighboring regions. These five are the two new species, *Nika bermudensis* and *Alpheus lancirostris*, and the eastern species, *Palæmonella tenuipes* (from the Sooloo Sea), *Leander affinis* (from Amboina), and *Penaeus velutinus* (from the Pacific). As to these three last-mentioned species, there is some reason for separating the Bermuda forms from their eastern allies ; but even if on further study this should prove advisable, it is clear that they are closely related to the species mentioned above. The same interesting relationship is shown in other forms as well,—as in the genus *Alpheus* we have the *A. hippothoë* var. *bahamensis*, which, as I noted in a previous paper, is very near the East Indian variety *A. edamensis ;* and the new species of *Nika* comes quite near the Amboinian *N. processa*.

With such exceptions, however, the crustacean fauna of Bermuda is most closely allied to its nearest neighbors, and it is probable that further investigations both in the Bermudas and the West Indies will show a still more complete similarity of the forms.

Many of the species, as is also the case with those found in the West Indies, have a distribution more or less widely extended in both hemispheres. I have reckoned that 18 out of the 61 are so distributed ; while 33 are, so far as known, confined to the West Indies and the coast of America, between, approximately, the Carolinas and Brazil. Two, *Panopeus herbstii* and *Alpheus candei*, belong to the east and west coasts of America ; and four, *Neptunus anceps*, *Calcinus tibicen*, *Alpheus hippothoë* var. *bahamensis*, and *Alpheus bermudensis*, belong to the West Indies alone, though it is highly probable that further research will discover them on the shores of the mainland. Of all the list, only three are known from Bermuda alone—the two new species described in this paper and *Paranebalia longipes*.

The expedition is entitled to the credit of adding eight species to the crustacean fauna of Bermuda, *i. e. Panopeus herbstii*, *Neptunus spinimanus*, *Nika bermudensis*, *Leander natator*, *Alpheus lancirostris*, *A. hippothoë* var. *bahamensis*, *Lepas anatifera* and *L. pectinata*.

DECAPODA.

OCYPODIDÆ.

1. **Ocypode arenaria** (Catesby).

Cancer arenarius Catesby, History of the Carolinas, II., p. 35, 1771.

One ♂ from South Shore, '97; one ♀, sandy beach, Cooper Island, '98. Reported by Miers.

Distribution: South shore of Long Island, to Brazil; West Indies.

GECARCINIDÆ.

2. **Gecarcinus lateralis** (Freminville).

Ocypoda lateralis Freminville, Ann. Sci. Nat. (2), III., p. 224, 1835.

7 ♂, 3 ♀, Castle and Cooper Island, '97. Burrows in the sandy soil among the grass. Seen also on the small islands off "Seaward," Bailey's Bay.

Reported by Heilprin, Miers, and J. M. Jones.

I am inclined to consider *G. lateralis* and *G. ruricola* (Linnaeus) as synonyms; but as my specimens correspond to Milne-Edwards' description "Tarses armés de *quatre* rangées d'épines" (Hist. Nat. Crust., II., p. 27, 1834), while the two specimens from the Bahamas which I have examined have *six* rows, and therefore would be M.-Edwards' *G. ruricola*, I adopt Heilprin's determination until a more complete series from both the Bermudas and West Indies may be examined.

Miers' reported *G. lagostoma* is probably, as Heilprin suggests, also *G. lateralis*.

Distribution: West Indies; Florida Keys.

*3. **Cardisoma guanhumi** Latreille.

Reported by Miers.

Distribution: East and west Central America; West Indies; West Africa.

NOTE.—Species prefixed by (*) are not in the collections of the N. Y. University Expeditions. They are placed in their appropriate place in order to make the list consecutive.

GRAPSIDÆ.

4. **Sesarma cinerea** (Say).

Grapsus cinerea Say, Jour. Acad. Nat. Sci. Philadelphia, I., p. 442, 1818.

Several specimens from the Flatts and Bailey's Bay, '98.

Very numerous at the Flatts on rocks above high water mark. They run very rapidly and conceal themselves under stones when pursued. They may not uncommonly be found on the trunks of the juniper trees, the bark of which they resemble in color. One specimen was taken as high as two feet from the ground.

Reported by Heilprin, from the Flatts; Whitfield collection.

Distribution: Virginia to Florida; West Indies.

*5. **Cyclograpsus integer** Milne Edwards.

Reported by Heilprin; Goode collection.

Distribution: Florida; West Indies; Brazil.

6. **Pachygrapsus transversus** (Gibbes).

Grapsus transversus Gibbes, Proc. Am. As. Adv. Sci., III., p. 181, 1850.

Numerous specimens from the tide pools under stones in Castle Harbor and Bailey's Bay, '97 and '98. They conceal themselves among the stones which they somewhat resemble in color. It seems to be the most common littoral crab.

Reported by Heilprin, Miers and Ortmann; Goode collection.

Distribution: warm and temperate waters of both hemispheres.

*7. **Pachygrapsus gracilis** (Saussure).

Goode collection.

Distribution: Florida; West Indies; Yucatan.

8. **Nautilograpsus minutus** (Linnæus).

Cancer minutus Linnaeus, Sys. Nat., Ed. X, I., p. 625, 1758.

Numerous specimens found, in '97, in the tide-pools with *Pachygrapsus* among the Sargassum in which it lives, and is so found distributed over the shores of the Atlantic, Pacific and Indian oceans.

Reported by Heilprin—"one small specimen." Goode collection.

9. **Grapsus grapsus** (Linnæus).

Cancer grapsus Linnaeus, Sys. Nat., Ed. X, I., p. 630, 1758.

3 ♂, 2 ♀. On rocks of Castle and Cooper Islands and on South Shore '97 and '98. These brilliantly colored crabs, though quite common on the surf-beaten rocks of the islands, are difficult to collect, as they make their way with surprising activity over the jagged coral cliffs, disappearing suddenly into narrow clefts or dropping into the boiling surf below.

Reported by Heilprin and Miers (*G. maculatus*).

Distribution: Warm seas of both hemispheres.

10. **Goniopsis cruentatus** (Latreille).

Grapsus cruentatus Latreille, Hist. Nat. des Crust., VI., p. 70, 1803.

2 ♂, 1 ♀, 1 ♀ juv. Longbird Island, at end of the St. George causeway, '98. Very numerous among the mangroves at this place. The crabs are exceedingly wary and at the slightest disturbance hide themselves among the roots of the mangroves or in the crevices of the causeway wall.

Reported by Heilprin and Miers from Hungry Bay.

Distribution: Florida to Brazil; West Indies; West Africa.

CANCRIDÆ.

11. **Eriphia gonagra** (Fabricius).

Cancer gonagra Fabricius, Sp. Ins., p. 505, 1781.

2 ♀ with ova. Cooper Island, near shore, '97.

Reported by Miers "a small adult male."

Distribution: Atlantic coast, South Carolina to Brazil; West Indies.

12. **Panopeus herbstii** M.-Edwards.

M.-Edwards, Hist. Nat. Crust., I., p. 403, 1834.

(*a*) 1 ♂. No locality noted, '97.

A large specimen, 40 mm. long, and 61 mm. wide. In the form of its abdomen and the antero-lateral teeth this specimen resembles very closely the figure and description of *P. validus* Smith from the west coast of Central America, given by Benedict and Rathbun (Proc. U. S. Nat. Mus., XIV., p. 362, 1891). Probably *P. herbstii* and *P. validus* represent the east and west coast forms of the same species.

(*b*) 1 ♂, 1 ♀, under stones Long Bird Island, '98. The ♂ is 22 mm. × 34 mm. As the stones are lifted it is quite possible to overlook the crab, so close is its resemblance to the mud in which it lies concealed.

Heilprin, Miers and Ortmann report *P. herbstii* var. *serrata* Saussure ; and J. M. Jones previously reported the same. These were small specimens—probably *P. bermudensis*. *P. herbstii* I consider new to the Islands.

Distribution : Rhode Island to Brazil ; West Indies ; probably west coast of Central America.

13. **Panopeus bermudensis** Benedict and Rathbun.

Benedict and Rathbun, The Genus Panopeus. Proc. U. S. Nat. Mus., XIV, p. 376, pl. XX, 1891.

Numerous specimens from Bailey's Bay and Coney Island and dredged at the Flatts, '98.

The average size of the male is 9.5 mm. long and 13 mm. broad.

They may be found at low tide under stones in small depressions in the sand. They are variously colored, dark, light or mottled, corresponding to their surroundings. The fingers vary considerably ; sometimes quite dark, frequently as light as the palms. I find a large tooth on the dactyl of the larger hand in all but two specimens.

Collected at Bermuda by G. Brown Goode (B. & R., l. c. supra. p. 377) ; and probably the *P. herbstii* var. *serratus* of the other reports belongs here.

Distribution : Florida Keys to Brazil ; West Indies.

*14. **Eurytium limosum** (Say).

Reported by Miers.

Distribution : New York to Brazil ; West Indies.

15. **Actaea setigera** (Milne-Edwards).

Xantho setiger Milne-Edwards, Hist. Nat. Crust., I., p. 390, 1834.

Actaea setigera A. Milne-Edwards, Nouv. Crust. du Museum, I., p. 271, pl. XVIII., fig. 2, 1865.

1 ♂, Castle Harbor, under stones at low tide, '98.

Purplish-red in color, lighter on appendages; fingers and lower portion of hand black. Size, 40 mm. broad, 27 mm. long.

An unusually broad specimen, probably quite old.

Reported by Heilprin, "one male dredged off Shelly Bay," and by Ortmann. Whitfield collection.

Distribution: Florida Keys; West Indies.

16. **Xantho denticulata** White.

White, Ann. and Mag. Nat. Hist. Ser. 2, II., p. 285, 1849.

1 ♂, Cooper's Island, '97.

Reported from Bermuda by J. M. Jones; Goode collection.

Distribution: West Indies; Mexico; Brazil.

* 17. **Lophactaea lobata** (Milne-Edwards).

Goode collection.

Distribution: Florida Keys; West Indies.

* 18. **Lobopilumnus agassizii** Stimpson.

Reported by Heilprin; Goode collection.

Distribution: Florida.

PORTUNIDAE.

19. **Callinectes ornatus** Ordway.

Ordway, Boston Jour. Nat. Hist., VII., p. 571, 1863.

1 ♂ spurious, 4 ♀. Bailey's Bay at low tide, '97 and '98.

Olive-green carapace, appendages marked with blue.

Reported from Bermuda by J. M. Jones; Goode collection.

Distribution: South Carolina to Brazil; West Indies.

* 20. **Callinectes sapidus** Rathbun.

Reported by Rathbun in Proc. U. S. Nat. Mus., XVIII., p. 352, 1896.

J. M. Jones reports *Lupa diacantha*.

Distribution: Cape Cod to Texas; Jamaica; Brazil.

21. **Neptunus anceps** De Saussure.

H. de Saussure, Crust. Nouv. des Antilles et du Mexique, in Mém. de la Soc. Phys. Hist. Nat., Genève, XIV., p. 434, pl. II., fig. 11, 1858.

1 ♀, Cooper Island, '97. Length 18 mm., width 30 mm. Heilprin in his list, gives *N. hastatus* which is a Mediterranean species. A. Milne-Edwards in his key to the species of *Neptunus* (Arch. Mus. H. N., Paris, t. X., p. 326, 1861), makes the difference between *N. hastatus* and *N. anceps* consist in the breadth of the last two segments of the male abdomen. As my single specimen is a female I cannot verify this statement, but have no doubt that the Bermuda form is *N. anceps*.

Distribution: "The Antilles, taken at Cuba," Saussure.

*22. **Neptunus sayi** (Gibbes).

Reported by Ortmann; Goode collection.

Distribution: Atlantic coast of North America; West Indies.

23. **Neptunus (Acheloüs) spinimanus** (Latreille).

Portunus spinimanus Latreille, Nouv. Dict. Hist. Nat., XXVIII., p. 47, 1819.

Acheloüs spinimanus A. M.-Edwards, Arch. Mus. H. N. Paris, X., p. 34, pl. 32. 1861.

The single specimen was presented to me by Rev. H. J. Wood of St. George, who had obtained it from some fishermen of St. David's, '97. The carapace is covered with a close drab-colored pubescence except on ridges which are smooth and brownish-red. Pereiopods marked with longitudinal white stripes. Length 60 mm. breadth 100 mm.

This species has not before been recorded from Bermuda and, according to Mr. Wood, had never before been observed.

Distribution: South Carolina to Brazil; West Indies; Chili, (A. M.-Edwards).

24. **Neptunus (Acheloüs) depressifrons** Stimpson.

Amphitrite depressifrons Stimpson, Ann. Lyc. Nat. Hist. N. Y., VII., p. 58, 1862.

Acheloüs depressifrons Stimpson, ibid., p. 223.

1 ♀, Coney Island, in the sand at low tide, '98.

Color of carapace—above mottled like the sand, below, white, giving it a close resemblance to its environment. Small red markings on fingers of chelipeds and on propodos of second pereiopods. Length, 14 mm; breadth, 19 mm.

Reported by Miers, "an adult male"; Goode collection.

Distribution; South Carolina to Florida; West Indies.

* 25. **Portunus (Acheloüs) sebae** M.-Edwards.

Goode collection.

Distribution: Coast of North America.

INACHIDÆ.

* 26. **Podochela riisei** Stimpson.

Reported by Miers.

Distribution: West Indies and Brazil.

PERICERIDÆ.

27. **Macrocoeloma trispinosa** (Latreille).

Pisa trispinosa Latreille, Encyc. Méth. Hist. Nat., X., p. 142, 1825.

1 ♀. The cove at Coney Island, '98.

Reported by Miers—two specimens, and by Ortmann; Whitfield collection.

Distribution: North Carolina to Brazil; West Indies.

28. **Microphys bicornutus** (Latreille).

Pisa bicornuta Latreille, Encyc. Méth., X., p. 141, 1825.

Numerous specimens from Bailey's Bay, Castle Harbor, and White Island in Hamilton Harbor. Common.

Reported by Heilprin, Miers, J. M. Jones[1] and Ortmann.

Distribution: Florida to Brazil; West Indies.

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[1] Jones reports, "*Pericera cornuta*, from fish pot." It is probable that *Microphys bicornutus* is meant.

29. **Mithrax hirsutipes** (Kingsley).

Mithraculus hirsutipes Kingsley, Proc. Ac. Nat. Sci. Phil., p. 389, pl. 14, fig. 1, 1879.

Mithraculus forceps A. Milne-Edwards, Miss. Sci. au Mexique, pt. 5, I., p. 109, (?) 1880.

Numerous specimens from Castle Harbor in tide pools, and dredged, '97 and '98.

This and *Pachygrapsus transversus* were the most common species noted.

I consider that the name *M. hirsutipes* should take precedence over *M. forceps* as the latter does not seem to have been published until 1880, although the "Mission scientifique," in which the name appears, bears the date on the title page of 1875.

Reported by Heilprin (3 specimens), Miers (1 specimen) and Ortmann; Goode and Whitfield collections.

Distribution: North Carolina to Brazil; West Indies.

* 30. **Mithrax hispidus** (Herbst).

Goode collection.

Distribution: Florida to Brazil; West Indies.

* 31. **Mithrax (Nemausa) rostrata** A. M.-Edwards.

Reported by Miers.

Distribution: Gulf of Mexico.

CALAPPIDÆ.

32. **Calappa flammea** (Herbst).

Cancer flammea Herbst, Natur. Krabben u. Krebse, II., p. 161, 1793.

Miers, Challenger Brachyura, p. 284 (for synonomy).

4 ♂, St. David Island, Coney Island and Bailey's Bay, in shallow water, '97 and '98. One was taken while exuviating; the crab was nearly buried in the sand, with the posterior margin of the carapace alone protruding.

Reported by Heilprin, Miers and Ortmann.

Distribution: North Carolina to Venezuela; West Indies; East Indies and Cape of Good Hope.

* 33. **Calappa gallus** (Herbst).

Reported by Miers.

Distribution: East and West Indies; Red Sea.

HIPPIDÆ.

34. **Remipes cubensis** Saussure.

Saussure, Rev. Mag. Zoöl., ser. 2, IX., p. 503, 1857.

Hippa scutellata (Fabricius), Sp. Ins., II., p. 474, 1793.

Eighteen specimens from the sandy beach of Cooper Island, '97.

Reported by Henderson. Jones reports "Hippa or sand-bug."

Distribution: American and African shores of Atlantic.

PORCELLANIDÆ.

35. **Petrolisthes armatus** (Gibbes).

Porcellana armata Gibbes, Proc. Am. As. Adv. Sci., III., p. 190, 1850.

Numerous specimens from under stones in tide pools. Castle Harbor, Bailey's Bay and Harrington Sound, '97 and '98.

The specimens present considerable variation in the color—dark-blue, speckled, reddish-white and slate.

Reported by Heilprin, Henderson, Ortmann.

Distribution: Circumtropical.

CŒNOBITIDÆ.

*36. **Cœnobita diogenes** (Latreille).

Reported by J. M. Jones, Heilprin; Goode collection.

Since leaving the islands I have seen several living specimens from near the Flatts, but none were collected by the party.

Distribution: West Indies to Brazil.

37. PAGURIDÆ.

37. **Calcinus tibicen** (Herbst).

(Plate XVII., Fig. 1.)

Cancer tibicen Herbst, Naturg. Krab. u. Krebse, II., p. 25, pl. XXIII., fig. 6, 1796.

Pagurus sulcatus M.-Edwards, Hist. Nat. Crust., II., p. 230, 1834.

Not Calcinus tibicen (M.-Edwards), l. c. p. 229; Dana (Crust., p. 458); and authors.

The original description of *Cancer tibicen* by Herbst, as pointed out by Hilgendorf (see Henderson, Chal. Anomura, p. 61.), agrees with the West Indian *C. sulcatus* (M.-Ed.); and the *C. tibicen*, as described by Milne-Edwards from the South Seas, is another species. I consider, therefore, that this Bermudan and West Indian form should take the name *C. tibicen* (Herbst), and that *C. sulcatus* (M.-Ed.) should be a synonym. Milne-Edwards' short description of *C. sulcatus* agrees well with my specimens, except that the furrow on the propodos of the third pereiopod is placed by him, probably by mistake, on the *right side* instead of the *left.*

Heilprin, in his list, identifies his specimens as *C. obscurus* Stimp. (Annals Lyceum Nat. Hist. N. Y., VII., p. 83, 1862). As Stimpson's specimens are from Panama, and as he describes the ambulatory feet as "dark-olive, almost black," it is probable that these Bermuda forms should not be referred to *C. obscurus.* I add from my material a more complete description of the species:

Calcinus tibicen (Herbst).

Carapace and appendages minutely and closely punctate. Carapace and chelipeds reddish-brown, a darker area in center of tergum; back of cephalo-thoracic groove lighter, more or less mottled with dark spots; rostrum minute; optic peduncles above orange, slightly darker at ends, terminating distally with a white band; below of a lighter shade, longer than the peduncles of the inner antennae. Ocular scales appressed, triangular, with red base and white tips; cornea black.

Inner antennæ: dark-brown peduncle and orange flagellum. Outer antennæ; basal joint and spine dark-red, distal joint and flagellum orange. First pair of pereiopods: chelæ reddish-brown, tips of fingers white, somewhat excavated; the upper margin of smaller hand with blunt keel and without any serrations.

Second and third pairs of pereiopods slightly lighter in color than the first; propodos with only a few hairs at its distal end, yellowish-white; dactyl of same color but with a median circular band of reddish-brown and a black tip. On the outer surface of the propodos of the third pereiopod of the *left side* is a broad and shallow, but well marked, longitudinal furrow.

Eight specimens, several with ova. In various gastropod shells, found under stones on shore of Castle Harbor and dredged in the channel, '97.

Distribution: West Indies.

38. **Clibanarius tricolor** (Gibbes).

Pagurus tricolor Gibbes, Proc. Am. As. Adv. Sci., III., p. 189, 1850.

Numerous specimens in various small spiral shells from Bailey's Bay and Castle Harbor '97 and '98. Several specimens were collected which had adopted the shell of the Pulmonate, *Bulimus decollatus,* as their habitation.

This brightly colored and very active little hermit crab is very abundant among the stones in tide-pools.

Reported by Heilprin; Goode collection.

Distribution: Florida and West Indies.

SCYLLARIDÆ.

39. **Scyllarus æquinoctialis** Lund.

Lund, Skrivter Naturh. Selsk., II., pt. 2, p. 21. Copenhagen 1793.

Three specimens, 2 ♂, 1 ♀, bought from fishermen were sent alive to the New York Aquarium in '97, but did not survive.

Hielprin reports a *Scyllarus sculptus* M.-Edwards, purchased at the Crawl. My specimens differ from M.-Edwards' description of *S. sculptus* in the lack of the median spines and it is probable that *S. æquinoctialis*—the common West Indian form, is the one reported by Hielprin rather than *S. sculptus.*

Reported also by J. M. Jones.

Distribution: West Indies to Brazil.

PALINURIDÆ.

40. **Panulirus argus** (Latreille).

Palinurus argus Latreille; Milne-Edwards, Hist. Nat. Crust., II., p. 300, 1837.

2 ♂ juv. Locality not noted, '97. Two adult specimens were sent to the N. Y. Aquarium for exhibition, but did not survive the journey. This is the "lobster" of the Bermudas; its large size and brilliant coloring make it by far the most striking of the Bermuda Crustacea.

Heilprin reports "*Palinurus americanus* Lamk., the large Bermuda Crayfish." As he says however that "I am unable to state positively if the species is correctly referred," it is probable that his species should also be *P. argus*.

Reported also by Jones; Whitfield collection.

Distribution: Florida Keys; West Indies to Brazil.

STENOPIDÆ.

*41. **Stenopus hispidus** (Latreille).

Reported by Spence Bate.

Distribution: warm waters of both hemispheres.

NIKIDÆ.

42. **Nika bermudensis** n. sp.

(Plate XVII., Fig. 2.)

Three specimens, 2 ♀ with ova, 1 ♂. Harrington Sound, dredged at a depth of one fathom in clean white sand, '98. I am indebted to Mr. F. W. Carpenter of New York University for these specimens.

Rostrum one-third the length of the cephalo-thorax, somewhat shorter than the opthalmapoda, spiniform, not extending backward as a keel, bifid at apex, the lower tooth being the longer, projecting beyond the teeth on both sides are two hairs.

Anterior margin of carapace produced into a small rounded antennal angle, not spiniform, no ocular tooth. Fronto-lateral angle rounded.

First pair of antennæ: basal joint of pedicel reaches beyond the tip of rostrum, second and third joints together not so long as the first, third a little shorter than the second; outer flagellum robust, equal in length to the pedicel, basal two-thirds fringed with long cilia; inner flagellum slender, rather more than twice the length of outer.

Second pair of antennæ: scaphocerite almost as long as the pedicel of the inner antennæ, a spine on its distal, outer angle; flagellum a little longer than the body.

Third pair of maxillipedes: the two terminal joints together a little shorter than the antepenultimate; distal end of penultimate reaches the tip of pedicel of inner antennae.

First pair of pereiopods: robust, shorter than the third maxillipede, that on the left side terminates in a claw, on the right side in a small chela; the three terminal segments together equal in length to the meros. Second pair of pereiopods: very slender and chelate, that on the left side, when extended, reaches slightly beyond third maxillipede, that on the right ride about one-third longer; a bunch of fine hairs at the base of the hand; carpus multiarticulate; the ischium of both limbs has a sheath-like posterior outgrowth. Third, fourth and fifth pairs of pereiopods long and slender, terminating in sharp claws, each of which has a bunch of fine hairs at its base and a few minute hairs near the tip; third and fifth pairs sub-equal, fourth noticeably longer, principally on account of the greater relative length of the meros and carpus so that the dactyl and part of the propodos reach beyond the end of the third and fourth; meros of the third pair has five backwardly projecting spines.

Telson: tapering to the apex, which terminates in a spine on either side; dorsal surface grooved, with two pairs of dorsal spines.

Total length of a female, 14 mm., cephalo-thorax, 9 mm.

This is the first recorded appearance of a *Nika* in the western Atlantic. The five described species of the genus are as follows:

1. *Nika edulis* Risso (Hist. Nat. Crust., Nice, p. 85, pl. 3, fig. 3, 1816). = *Processa canaliculata* Leach (Malacost, Pod. Brit., pl. I. 1818), Seas of Europe, Madeira, Cape Verde, Japan.

2. *N. japonica* De Haan (Fauna Japonica, pl. 46, fig. 6, 1850). East Coast of Asia.

3. *N. hawaiensis* Dana (U. S. Expl. Ex., Crustacea, p. 538, 1852). Hawaii.

4. *N. macrognatha* Stimpson (Proc. Phil. Ac., p. 27, 1860). Hong-Kong.

5. *N. processa* Spence Bate (Challenger, Macrura, p. 527, pl. 95, 1888). Amboina.

The more marked differences between the Bermuda species and the others are the following: *N. edulis* has a keel on the rostrum; in *N. hawaiensis* the rostrum is broad and triangular; *N. japonica* has no spines on the upper surface of the telson; *N. macrognatha* has smaller eyes and longer maxillipedes; *N. processa*, to which the new species is most closely allied, has a longer rostrum, longer maxillipedes and pereiopods, the carpus of the 3d, 4th and 5th pereiopods is equal to the meros and ischium together (in *N. bermudensis* the carpus is equal only to the meros), the second joint of the pedicel of inner antennæ is relatively longer than in *N. bermudensis*, where it very slightly excels in length the terminal joint.

From all these species *N. bermudensis* differs in having a bifid rostrum.

PALÆMONIDÆ.

43. **Palæmonella tenuipes** Dana.

Dana, Crust. U. S. Expl. Ex., p. 582, pl. 38, fig. 3, 1852.

1 ♂, 1 ♀ with ova. Broken out of coral rock in Castle Harbor, 6–8 feet, '97.

These two specimens belong, no doubt, to the same species as those dredged by Heilprin in Shelly Bay and referred by him to Dana's *P. tenuipes* from the Sooloo Sea. I note eight dorsal spines on rostum instead of seven, and no spines on carpus of the second pereiopod. Probably a new species should be made for this Bermuda form.

44. **Leander natator** (Milne-Edwards).

Palæmon natator M.-Edwards, Hist. Nat. Crust., II., p. 393, 1837.

This single specimen was found in '97, in a tide pool at Castle Island under masses of Sargassum with which it had undoubtedly reached the island, as it is a sargassum-living form and is so distributed throughout the warmer seas. I find on the rostrum eleven dorsal, and four ventral teeth.

Not before reported from the Bermudas.

45. **Leander affinis** (Milne-Edwards).

Palæmon affinis Milne-Edwards, Hist. Nat. Crust., II., p. 391, 1837.

Numerous specimens, usually with ova. Very common in pools among the rocks on the shores of Castle Harbor, '97 and '98.

As noted by Heilprin the number of rostral teeth varies considerably. The only difference from Spence Bate's description (Chal., Macrura, p. 782) of his Australian form seems to be that in the Bermuda form the ocellus is not clearly distinct from the cornea of the eye, as Spence Bate gives it, but lies just within its margin.

Reported by Heilprin and Ortmann; and by J. M. Jones as *Palæmon vulgaris*.

Distribution: New Zealand (Dana); Port Jackson (Bate).

ALPHEIDÆ.

46. **Alpheus edwardsii** (Audouin).

(Plate XVII., Fig. 3.)

Athanas edwardsii Audouin, Planches de la déscription de l'Egypte par M. Savigny, Crust. pl. X., fig. 1, 1810.

Three specimens from Castle Harbor, '97.

Reported by Heilprin and Ortmann.

Distribution: Circumtropical.

47. **Alpheus hippothoë** de Man. var. **bahamensis** Rankin.

Rankin, Annals N. Y. Acad. Sci., XI., p. 247, pl. XXX., fig. 5, 1898.

Four specimens, St. David Island, in tide pools, '97.

These specimens have the characteristic blue tips of the fingers.

New to Bermuda.

Distribution: Bahamas.

48. **Alpheus bermudensis** Spence Bate.

(Plate XVII., Fig. 4.)

Spence Bate, Chalenger, Macrura, p. 547, pl. 98, fig. 3, 1888.

(*a*) 3 specimens from dredger, '97. (*b*) 9 specimens from Bailey's Bay, under rocks at low tide, '98. (*c*) 2 specimens dredged in 1–2 fathoms at the Flatts, '98.

Heilprin considers that *A. bermudensis* is the same as *A. avarus* Fabr. and *A. edwardsii* Audouin. The synonomy of the two latter is probable; but there are well marked differences in specimens of the same size of *A. bermudensis* and *A. edwardsii.* In *A. edwardsii* there is a deep transverse constriction in the larger chela above and below; in *A. bermudensis* only above as shown in the figure (plate XVII., fig. 4). A deep longitudinal furrow is on the inner side near the upper surface of *A. bermudensis*, none in *A. edwardsii* (cf. fig. 3). The dactyl is longer and less sickel-shaped in *A. edwardsii*, and on the meros is a spine at the distal inner end. The carpal joints of the second pereiopods also differ, the first in *A. bermudensis* being shorter than the second, instead of longer, while the third and fourth are proportionately shorter than is the case in *A. edwardsii.* The small chela of *A. bermudensis* is very much smaller than the large; the fingers are about the length of the palm, slightly gaping, as the dactyl has a long slight curve.

Reported by Heilprin and Spence Bate, who also had a specimen from St. Thomas, W. I.

49. **Alpheus minor** Say.

Say, Jour. Acad. Nat. Sci. Phil., I., p. 245, 1818.

Numerous specimens from the dredger, '97, and broken out of coral rock in Castle Harbor, '97 and '98.

Reported by Heilprin and Ortmann.

Distribution: Virginia to Panama; West Indies; west coast Central America.

50. **Alpheus candei** Guerin.

Guerin, in Sagra's Histoire de l'isle de Cuba, Paris, p. L, pl. II., fig. 9, 1857.

Alpheus transverso-dactylus Kingsley, Bull. U. S. Geol. Survey, IV. (no. I.), p. 196, 1878.

Seven specimens of a yellowish-green color with darker green carapace broken out of coral rock in Castle Harbor '97 and '98.

The description given by Kingsley (l. c. supra) of specimens from California corresponds very closely to Guerin's figure of his specimens from the coast of Cuba and to my material from Bermuda. I think there can be no doubt that *A. transverso-dactylus* Kingsley should be considered as a synonym of *A. candei* Guerin. Kingsley himself says "I cannot separate from this, i. e., the Californian *A. transverso-dactylus*, two specimens from Bermuda, one collected by J. M. Jones and the other by G. Brown Goode." This species comes near *A. streptochirus* Stimp. from the Cape Verde Islands.

Reported by Kingsley from Goode and Jones collections.

Distribution: California; West Indies.

51. **Alpheus lancirostris** n. sp.

(Plate XVII., Fig. 5.)

Nineteen specimens, 11 ♂, 8 ♀; two from dredger '97, the remainder from under stones in Bailey's Bay, at low tide, '98.

Carapace smooth. Rostrum prominent, laterally compressed and slightly bent down at tip, extending backward as a sharp lance-like keel to the posterior region of cornea where it broadens out to a triangular base; the keel is separated from the ocular lobes by a broad and well marked sulcus. Ocular lobes prominent dorsally; no spine, but slightly angular anteriorly.

Inner antennæ: basal joint of peduncle reaching to the tip of rostrum, with a sharp spine equal in length to the basal joint; two following joints cylindrical, the third half the length of second; upper flagellum short and stout, tipped with a long pencil of hair; inner flagellum rather more than twice the length of outer. Outer antennæ: basal joint of peduncle with short spine;

scaphocerite slightly longer than peduncle, ends in a stout spine, lamellar portion narrowed at base; flagellum nearly twice the length of the longer flagellum of inner antennæ, about equal to the body length.

First pair of pereiopods: meros triangular in cross section, a spine at the distal end of the inner lower margin; carpus short; large hand much swollen, a deep narrow sulcus on upper margin, a depression on inner lateral surface running backwards and downwards from this, a shallower depression on the outer surface; a sulcus on the lower margin constricts the palma sharply from the thumb; dactyl strongly arched, very little longer than the thumb; articulation vertical; tip of dactyl and of thumb calcareus; scattered hairs on hand and dactyl; the whole aspect of the large hand, which appears to be always on the right side, is very similar to that of *A. edwardsii* (cf. pl. XVII, fig. 3); small hand cylindrical, long and slender, fingers nearly straight, as long as palma, slightly hairy.

Second pair of pereiopods: carpus five-articulate; first and second joints subequal, third and fourth equal, together about the length of fifth, which is shorter than the second; hand slightly longer than fifth carpal joint.

Third and fourth pairs of pereiopods similar, no meral spine. Fifth pair of pereiopods more slender than fourth. Propodos of third, fourth and fifth pairs fringed with small spines; their dactyls slender and sharp.

Pleopods slender; in the females loaded with well developed ova. Telson rounded at distal extremity, lateral margins slightly concave; two small spines on each side of median line of dorsal surface. Uropods rounded at distal end; outer one with well-marked diæresis; the outer angle of proximal portion is marked by a minute spine and a longer articulated one is median to this.

Color of fresh specimens: three broad, transverse bands of brown on the carapace and one on each segment of the abdomen; antennæ and margins of the telson and uropods orange; pereiopods yellow; large chela spotted with brown and with an orange area on the inner side; ends of fingers white. In alcohol the species is characterized by alternate bands of pink and white, while the chelæ are mottled with blue.

The affinities of the new species are with *A. intrinsicus* Spence Bate from Bahia (Chal., Macr., p. 557. pl. III., fig. 1), In both the rostrum is broad and flat at the proximal end and the sharp keel is separated from the eyes by a deep and wide sulcus, but in the new species the broadening of the keel of the rostrum towards its distal end is not so prominent, and the sharp spines on the inner dorsal surface of the ocular lobes are wanting. The teeth on the large chela of *A. intrinsicus* are wanting in the new species, and also the meral spines of the third and fourth pereiopods. The carpus of the second pair of pereiopods is five-jointed in the new species, six-jointed (according to Spence Bate's figure and description) in *A. intrinsicus.*

Measurements of large ♀: total length, 45 mm.; length of carapace, 15 mm.; of large chela, 21 mm.; of small chela, 13 mm.

52. **Alpheus websteri** Kingsley.

Kingsley, Proc. Ac. Nat. Sci. Phil., p. 416, 1879.

Five specimens, dredged in channel, 6 fathoms, '97.

This is probably the same as *A. formosus* Gibbes (Proc. A. A. A. S. III. p. 196, 1850), though as I am in doubt about the exact synonomy I retain provisionally the name above.

The small black spines of the uropods noted by Kingsley serve readily to identify this species. The triangular rostrum with the lateral sulci clearly distinguish it from *A. minor*, and place it in the same group with the new species.

The specimens were at first marked by a white band along the median dorsal surface and a wavy line on each side.

Heilprin reports one specimen of *A. formosus* Gibbes, obtained by dredging.

Distribution: Florida and West Indies.

PENÆIDÆ.

53. **Sicyonia carinata** (Olivier) (?).

(Plate XVII., Fig. 6.)

Palaemon carinatus Olivier, Encyclop., t. VIII., p. 667, 1811.

Sicyonia carinata Milne-Edwards, Ann. Sci. Nat., ser. I., XIX., p. 344, pl. IX., fig. 9, 1830.

Sicyonia carinata Spence Bate, Challenger, Macrura, p. 294, pl. XLIII., figs. 2, 3, 1888.

Two damaged specimens. Harrington Sound, dredged in clean white sand with *Nika bermudensis*, 1 fathom. I am indebted to Mr. F. W. Carpenter, of the New York University, for the specimens dredged at this place in July, '98.

The specimens come near to, and perhaps are, the *S. carinata* Olivier, the only species of *Sicyonia* reported from the West Atlantic region. My specimens differ from the figures of Spence Bate and Milne-Edwards (cf. fig. 6) in the position of the rostral teeth, mine having four teeth close together on the dorsal surface of rostrum and none below. One other tooth is posterior to the gastric region. As the thoracic appendages are entirely wanting I am not able to make a careful comparison of the forms and leave the Bermuda species for the present as *S. carinata*.

Reported by Ortmann. 1 ♀.

Distribution: St. Thomas, W. I., and Brazil.

* 54. **Penæus constrictus** Stimpson.

Reported by Ortmann; Goode collection.

Distribution: Coast of North and South Carolina.

* 55. **Penæus velutinus** Dana.

Reported by Heilprin.

Distribution: Pacific.

* 56. **Pandalus tenuicornus.**

Goode collection.

PHYLLOCARIDA.

57. **Paranebalia longipes** (Willemoes Suhm).

Nebalia longipes Willemoes Suhm, Trans. Linn. Soc. Lond., ser. 2, I., p. 26, pl. VI., 1879.

Paranebalia longipes Sars, Report on the Phyllocarida, in Challenger Report, p. 10, 1887.

Two specimens, ♀, dredged at the Flatts, 1 to 2 fathoms in clean sand, '98.

The type specimens of the Challenger expedition came from Bermuda in Harrington sound. Also collected there by Dr. Goode.

Not reported from other localities.

STOMATOPODA.

58. **Pseudosquilla ciliata** Miers.

Miers, Ann. and Mag. Nat. Hist. ser. 5, V., p. 108, pl. III., figs. 7 and 8, 1880.

One specimen from dredger, '97.

Reported from Bermuda by Bigelow in Proc. U. S. Nat. Mus., vol. XVII., p. 499, 1894.

Distribution: Atlantic and Pacific.

59. **Gonodactylus œrstedii** Hansen.

Hansen, Isopoden, Cumaceen und Stomatopoden der Plankton-expedition, 1895, p. 65.

G. chiragra Fabricius (in part), Ent. Sys., II., p. 513, 1793.

Five specimens, broken from coral rock, Castle Harbor and Bailey's Bay, '97 and '98.

Reported by Heilprin, one specimen from Flatts; Brooks and J. M. Jones; Goode collection.

Distribution: West Indies; Florida to Brazil.

CIRRIPEDIA.

60. **Lepas anatifera** Linnæus.

Linnæus, Systema Naturæ, 1767.

Darwin, Monograph on Cirripedia, Lepadidæ, p. 73, 1851.

Several dried specimens from a log cast on the shore, '98.

Distribution: Common in all waters.

61. **Lepas pectinata** Spengler.

Spengler, Skrift. Nat. Sels., II, p. 106, 1793.

Darwin, Monograph on Cirripedia, Lepadidæ, p. 85, 1851.

One specimen attached to sargassum in water near North Rock, '98.

Distribution: Atlantic and Mediterranean waters.

PRINCETON UNIVERSITY, May, 1899.

PLATE XVII.

PLATE XVII.

Bermuda Crustacea.

PAGE.

Fig. 1. **Calcinus tibicen** (Herbst).
Cephalo-thorax, × 4 533

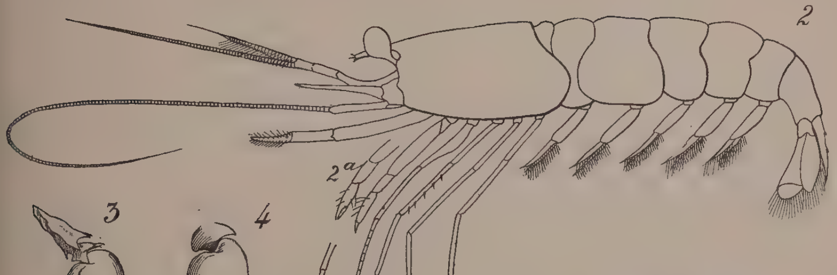
Fig. 2. **Nika bermudensis** Rankin n. sp., × 6 536
a. First pereipod of right side.
b. Second pereiopod of right side.

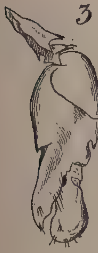
Fig. 3. **Alpheus edwardsii** (Audouin) 539
First pereiopod; larger chela (from De Man), × 1½.

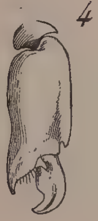
Fig. 4. **Alpheus bermudensis** Spence Bate 540
First pereiopod; larger chela (from Spence Bate), × 2

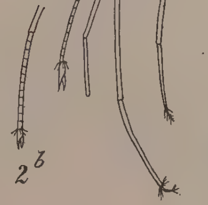
Fig. 5. **Alpheus lancirostris** Rankin n. sp., × 1½ 541
a. Cephalic region of carapace, dorsal aspect, × 4½.
b. First pereiopod; smaller chela, × 1½.
c. Telson, from above; × 1½.

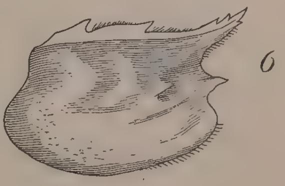
Fig. 6. **Sicyonia carinata** (Olivier) 543
Carapace (from Spence Bate), × 2.

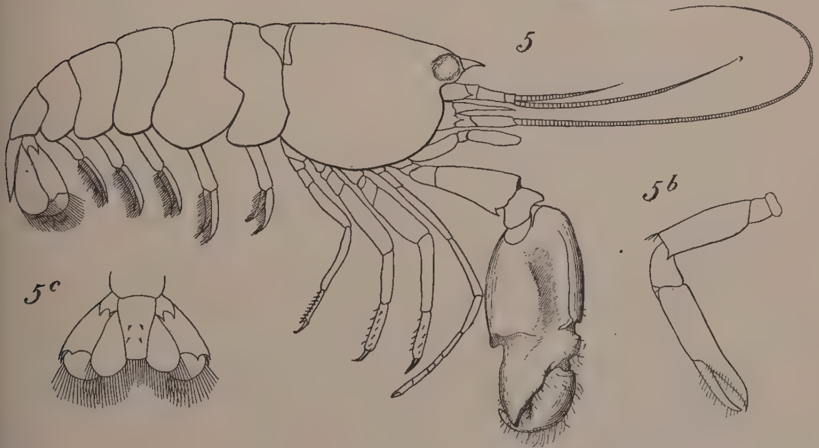


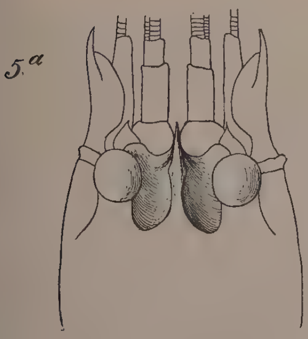


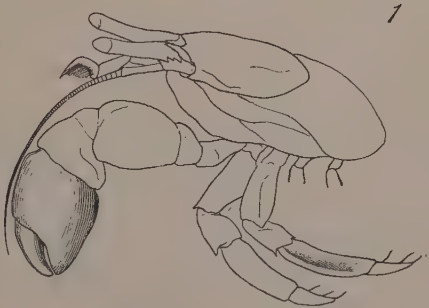












R. Weber, del.

[ANNALS N. Y. ACAD. SCI., Vol. XII., No. 13, pp. 549 to 588, May 22, 1900.]

CONTRIBUTIONS TO AVESTAN SYNTAX, THE CONDITIONAL SENTENCE.

LOUIS H. GRAY.

(Read March 27, 1899.)

AMONG the numerous problems presented to the scholar by the syntax of the Avesta[1] the question of the original distinction between the subjunctive and the optative is one of the most interesting.[2] The view of Delbrück with regard to this primary distinction between the two moods in Indo-Germanic has long been accepted by the majority of scholars. He formulated his opinion in the following sentence (Gebrauch des Conj. und Opt. 13): "Dieser relative Grundbegriff ist für den Conjunctiv der Wille, für den Optativ der Wunsch." "Will" is defined as a desire for the attainable; "wish" implies a longing for what may perhaps be unattainable (ibid. 16, cf. his Vgl. Synt. ii., 374). Delbrück has reiterated his view with regard to the fundamental difference between the subjunctive and optative more than once, and he still retains it as being the most probable working hypothesis in the study of the modal relations of the Indo-Germanic (Grundlagen der griech. Synt. 116–117, Altind. Synt. 302, Vgl. Synt. der Indo-Germ. Sprachen ii., 349–352). On the other hand, the same scholar, Grundlagen der griech. Synt. 117, recognizes the possibility of regarding the subjunctive as a nearer future and the optative as a remoter future. This is the view which has been maintained with much energy and feeling by

[1] My deepest indebtedness is due to my teacher, Professor Jackson, of Columbia University. It is his collection of examples from the Avestan texts that has formed the nucleus of the present paper. To him I express sincerest thanks.

[2] The principal literature as far as the Avestan is concerned is as follows: Spiegel, Gramm. der altbakt. Sprache 322, 337–338; Vgl. Gramm. der altérân Sprachen 499–504; Jolly, Conjunctiv und Optativ und die Nebensätze im Zend und Altper., especially 70–104; Bartholomae, Altiran. Verb. 181–219.

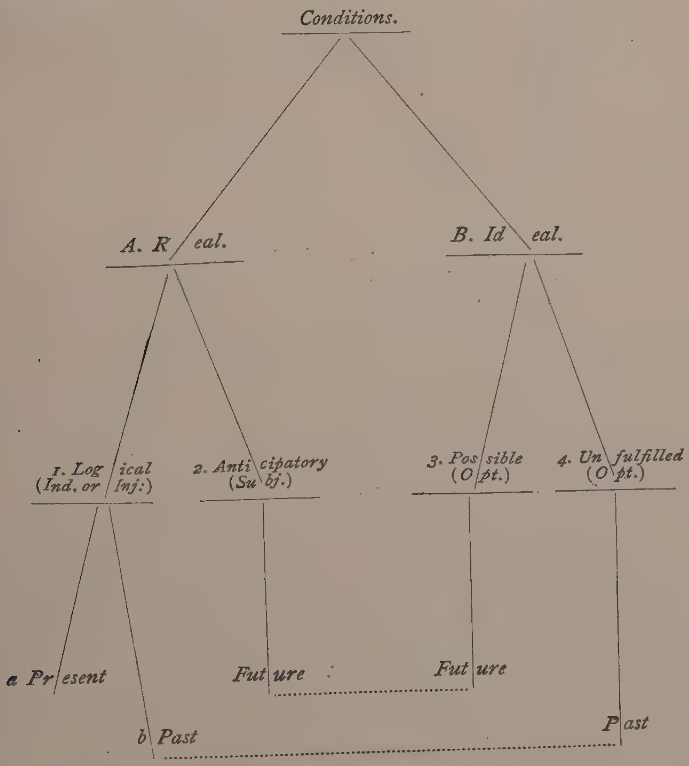
Prof. Goodwin of Harvard, in his "relation of the optative to the subjunctive and other moods" (Appendix i. of his 'Greek moods and tenses,' 371–389, edit. 1893). Thus Goodwin says, 389: 'Its (the optative's) relation to the subjunctive . . . is substantially that of a 'remoter future.'" The gulf between the views of these two scholars seems to me to be more apparent than real. Goodwin in particular seems to be a little too nice in his distinction between "will" and "wish." "Will" and "wish" in my judgment denote nothing more or less than different grades of desire, which itself of necessity implies future time. I emphasize this point, because, if it be granted, a synthesis of the views of Delbrück and Goodwin appears not impossible. I feel, then, little hesitation in adopting Delbrück's hypothesis. This will lead to the following classification of the uses of the subjunctive and optative (Vgl. Synt. ii., 374, cf. Gebrauch des Conj. und Opt. 16–17; Bartholomae Altiran. Verb. 181. See also the classification of Goodwin, 375, 388, and compare Elmer, Studies in Latin Moods and Tenses, Cornell Studies in Class. Philology vi., 175–231, Bennett, ibid., ix., 31–47):

a. Subjunctive = Will	*b.* Optative = Wish
Volitative Subjunctive	Prescriptive Optative
Prospective "	Potential "

Both the subjunctive and the optative, like the imperative, seem to have stood originally only in positive sentences. Their equivalent in negative sentences was the injunctive.

The conditional sentences fall into two main divisions, and each of these is to be divided in its turn into two classes. First of all, conditions are (1) real, (2) ideal. The real conditions fall into the two classes of (1) logical conditions ("if he goes, it is well"), (2) anticipatory conditions ("if he shall go, it will be well"). The ideal conditions are either (1) possible conditions ("if he should go, it would be well") or (2) unfilled conditions ("if he had gone, it would have been well"). The logical conditions have the indicative (or the injunctive) in the protasis; the anticipatory conditions contain the subjunctive in the protasis.

In both classes of the ideal conditions we find the Optative in the Protasis. With regard to the time-element of these classes of the conditional sentences, it is to be noted that the logical conditions fall either into the present or the past, while the anticipatory conditions are concerned with the future only. The possible conditions, like the anticipatory, imply future time; and the unfulfilled conditions, like one class of the logical, deal with the past. The following diagram may serve to make my divisions more clear.



First and foremost it must be observed that the class of a conditional sentence is determined in all cases by the mood (and tense) of its protasis. The form of its apodosis is a secondary matter.

With regard to my translations I have systematically rendered the subjunctive by "may" or "shall," and the optative by "might" or "should." Of these alternative renderings I have used "may" for what I regarded as the volitative subjunctive, and "shall" for the prospective. Similarly "might" translates the potential optative, and "should" the prescriptive. For an occasional violation of the English usage of "shall" and "will" I must plead the necessities of a scientific uniformity in so delicate a problem as the mutual relations of the moods. I have rendered the injunctive in all cases by "is to," and the future indicative by "will." While it is quite evident that the subjunctive and the optative are sometimes used in the conditional sentence with iterative force (cf. Jolly, Conj. u. Opt. 43–45, 59, 102, 85, 94; Bartholomae, Altiran. Verb. 188, 190–191, 194, 212, 216; KZ. xxviii., 37; Sprachgeschichte ii., 127; Jackson, Proc. A. O. S. xvii., 187 and especially the examples in his forthcoming Avestan syntax; cf. also the use of the subjunctive and the optative in Greek general conditions, Goodwin Greek moods and tenses 170 seqq., and the iterative subjunctive in Latin, Gildersleeve-Lodge Latin Gramm. 364), I have thought it best not to disturb the uniformity of my renderings for the sake of this special shade of meaning. It will, I hope, be readily deducible in all cases where it occurs, even from my translations.

In the discussion of the conditional sentence in the Avesta seventy-eight examples have been considered. Twenty-eight of these are Logical, thirty-three Anticipatory, nine Possible, and three Unfulfilled. The five remaining examples are conditions whose Protasis contains no finite verb. With regard to the portions of the texts whence the passages considered have been taken, twenty-four sentences are from the Gāthās, fifty-four from the Younger Avesta. Of the latter two are from the verse Yasna, four from the prose Yasna, one from mixed prose and verse Yasna. Nine are from the verse Yašts, four from the prose Yašts, six from mixed prose and verse Yašts. The Vendidād gives twenty-eight examples, all but one in prose. The data with regard to the Apodosis are as follows: Logical Conditions with Indicative in the Apodosis ten, Subjunctive six, Optative two, Injunctive two, Imperative two; Injunctive in the Protasis, and Injunctive in the Apodosis four, Subjunctive in the Apodosis one. Anticipatory Conditions with Subjunctive in the Apodosis fourteen, Indicative seven, Optative seven, Injunctive four, no finite verb one. Possible conditions with Optative in the Apodosis three, Indicative one, Subjunctive five. Unfulfilled Conditions with Optative in the Apodosis two, Subjunctive one. Conditional sentences with no finite verb in the Protasis have in the Apodosis the Indicative once, the Subjunctive twice, the Optative once, and the Imperative once. The single instance of a condition without an introductory conditional particle has the Indicative in both clauses.

The relative frequency of the moods in Protasis and Apodosis is as follows: Indicative, Protasis, twenty-three; Apodosis, twenty. Subjunctive, Protasis, thirty-three; Apodosis, twenty-nine; Optative, Protasis, twelve; Apodosis, fifteen. Injunctive, Protasis, five; Apodosis, ten. Imperative, Apodosis, three; no finite verb, Protasis, five; Apodosis, one.

Examples from the Gāthās are lacking only for the type Subjunctive + omitted verb, and Optative + Indicative. I am not able to quote at present a Gāthic example of the Unfulfilled Condition.

A. REAL CONDITIONS.

I. Real Conditions in the Present or Past—Logical Conditions.

a. Indicative in the Protasis.

a. Indicative in the both Clauses.

a. Present tense in both Clauses.

1. The Protasis is introduced by the general relative *ya*—:

ys. **33**. 2 (GAv. verse):

at̰ yə̄ akəm drəgvāitē vacaŋhā vā at̰ vā manaŋhā
zastōibyā vā varəšaitī vaŋhāu vā cōiθaitē astīm
tōi vārāi rādəntī ahurahyā zaošē mazdå.

'then whosoever will work harm to the wicked whether by word, or by thought, or by both hands, or doth instruct one in the good, they are responsive unto his will in their love of Ahura Mazda.'

(Note the Optative *varəšaētē* **S1.**)

ys. **38**. 4 (GAv. prose):

ūitī yā və̄ vaŋuhīš ahurō mazdå nāmą dadāt̰ vaŋhudå hyat̰ vå dadāt̰ tāiš vå yazamaidē tāiš fryąmahī tāiš nəmax́yāmahī tāiš išūidyāmahī.

'thus whatever good names Ahura Mazda, creator of good, gave you when he created you, we worship you with them, we delight you by them, we honor you by them, we claim you by them.'

yt. **10**. 28 (yAv. verse)—cf. also yt. **10**. 38:

āat̰ ahmāi nmānāi daδāiti
gə̄ušca vąθwa vīranąmca
yahva xšnūtō bavaiti
upa anyå scindayeiti
yāhva t̰bištō bavaiti.

'then to this house he giveth hosts both of kine and of male children, where he is well-pleased; others he doth destroy, where he is displeased.'

yt. **10**. 87 (yAv. verse):

āat̰ yahmāi xšnūtō bavaiti
miϑrō yō vouru-gaoyaoitiš
ahmāi jasaiti avaiŋ́he.

'then with whomsoever Mithra, lord of wide pastures, is well-pleased, to that man he comes for aid.'
(cf. the Subjunctive *uzjasāiti* in the similar sentence yt. **10**. 19.)

yt. **13**. 47 (yAv. verse):

yatāra vā dīš paurva frāyazənte
fraorət̰ fraxšni avi manō
zarazdātōit̰ aŋhuyat̰ haca
ātaraϑra fraorisinti
uγrå ašāunąm fravašayō.

'then whichsoever of the two doth first worship them very zealously in mind, from devotion of the soul, thitherward do turn the awful Fravashis of the righteous.'
(cf. the Subjunctive *frāyazāiti* in the similar sentence yt. **10**. 9.)

2. The Protasis is introduced by *yezi, yeδi:*

ys. **1**. 21 (yAv. prose):

yezi ϑwā didvaēša . . . ā tē aiŋ́he fraca stuyē nī tē vaēδayemi yezi tē aiŋ́he avā-urūraoδa yat̰ yasnaheca vahmaheca.

'if I have incurred thy displeasure . . . I praise thee therefor, I acknowledge thee, if I have fallen short in that which is worship or of prayer.'

ys. **62**. 9 (yAv. prose and verse):

āat̰ yezi šē aēm baraiti aēsməm . . .
ā hē pascaēta frīnaiti
ātarš mazdå ahurahe.

'if then he bringeth wood to him, . . . thereafter the Fire of Mazda Ahura blesseth him.'

(cf. vd. **18**. 26, where the Apodosis has the Subjunctive *āfrīnāṯ*.)

yt. **6**. 3 (yAv. prose):

yeiδi zī hvarə nōiṯ uzuxšyeiti aδa daēva vīspå mərəncinti yå hənti haptō-karšvōhva; nava ciš mainyava yazata aŋhava astvainti paiti-drąm nōiṯ paitištąm vīδənti.

'if the sun does not arise, then all the demons which are in the seven zones work destruction; neither do any spiritual angels in the material world find recourse or resistance.'

vd. **8**. 40–41 (yAv. prose):

zasta hē paoirīm frasnāδayən; āaṯ yaṯ hē zasta nōiṯ frasnāta āaṯ vīspąm hvąm tanūm ayaoždāta kərənaoiti . . .

yezica āpō vaŋuhīš barəšnūm vaγδanəm pourum paiti-jasaiti kva aēšąm aēša druxš yā nasuš upa-dvąsaiti.

'first they shall wash his hands; for when his hands (are) not washed, he maketh all his body in impurity . . .

'if the good waters come first to the top of his head where of these (places) doth this Druj, the Nasu, pounce.'

The following parallels for this form of the conditional sentence may be cited from the Rig-Veda, the Old Persian inscriptions, and the Greek.

Rv. **8**. 43. 28:

yád agnē divijā́ ásy apsujā́ vā sahaskr̥ta
tám tvā gīrbhír havāmahē.

'whether, Agni, thou art born in heaven or in water, O thou who wast made by might, we invoke thee with our hymns.'

Bh. **1**. 23-24:

yaϑāš[ām ha]cāmā aϑah y avaϑā akunavyatā.

'as it was said unto them by me, so was it done.'

Euripides Bellerophon. frag. 294, 7 (ed. Nauck):

εἰ ϑεοί τι δρῶσιν αἰσχρόν, οὐκ εἰσὶν ϑεοί.

b. Aorist tense in the Protasis and Present tense in the Apodosis.

1. The Protasis is introduced by the general relative *ya—:*

ys. **48.** 4 (GAv. verse):

yə̄ dāt̰ manō vahyō mazdā ašyascā
hvō daēnąm šyaoϑanācā vacaŋhācā
ahyā zaošə̄ng uštiš varənə̄ng hacaitē
ϑwahmī xratå apə̄məm nanā aŋhat̰.

'whoso hath made his mind better and more righteous, he doth follow the Faith both by deed and by word, (even) choices, longings (and) creeds: in thy sight at the last shall all men be.'[1]

(It is to be noted that *dāt̰* may possibly be regarded as a Subjunctive, cf. Jackson Av. Gramm. § 642.)

b. Indicative in the Protasis and Subjunctive in the Apodosis.

a. Present tense in both Clauses.

I. The Protasis is introduced by the general relative *ya—:*

vd. **7.** 25 (yAv. prose):

kat̰ tā nara yaoždayąn aŋhən . . . yā nasāum . . . frabarənti.

'how shall those men be purified . . . who bear forth . . . the corpse.'

(cf. the Subjunctive *fraŋuharāt̰* in the relative clause in the similar condition vd. **7.** 23 below.)

ys. **46.** 8 (GAv. verse):

yə̄ vā mōi yå gaēϑå dazdē aēnaŋhē
nōit̰ ahyā mā āϑriš šyaoϑanāiš frōsyāt̰
paityaogət̰ tā ahmāi jasōit̰ dvaēšaŋhā
tanvə̄m ā yā īm hujyātōiš pāyāt̰.

'or whosoever giveth these my creatures unto sin, never shall his dart cleave me by his deeds; on his body retributively should come with hatred those things which might hold him back from the good life.'

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[1] The Pahlavi tradition renders *a* 'unto the good, and even unto the evil' (*avŏ šapīrīh amatic avŏ sarītarīh*). For the asyndeton in *c* cf. ys. **33.** 2 and on *d* see Darmesteter's translation *ad loc.*

vd. **18**. 69–70 (yAv. prose):

yō . . . xšudrå avi fraŋharəzaiti hazaŋrəm anumayanąm frāvinuyāṯ . . . āϑre ašaya vaŋhuya frabarōiṯ.

'whosoever emitteth his seed, . . . he shall offer (?) a thousand sheep, . . . unto the Fire (Atar) with good piety should he present them.'

(Note the Subjunctive and the Optative side by side in the Apodosis of this sentence).

2. The Protasis is introduced by *yeδi, yezi:*

yt. **13**. 70 (yAv. verse and prose):

tå hē jasånti avaŋ́he
yezi šē bavainti anāzarətå.

'they shall come to his aid, if they are not distressed by him.' (cf. the Indicative *yūiδyeinti* in the similar passage yt. **13**. 63.)

vd. **6**. 28 (yAv. prose):

yezica aēte nasāvō friϑyeitica puyetica kuϑa tē vərəzyąn aēte yōi mazdayasna.

'and if these corpses be decayed and stinking, how shall these Mazdayasnians do?'

vd. **15**. 22 (similarly also vd. **15**. 16 and 40) (yAv. prose):

yezi nōiṯ harəϑrəm baraiti aētaδa aēte yōi spāna aδāityō-aŋharəϑrəm irišyąn para aēšąm irišintąm raēšō cikaēn baoδō-varštahe ciϑaya.

'if he does not take care, then these dogs shall receive harm, not being cared for according to the religion. For the wounds of those that have received harm they shall pay the penalty with the punishment of a Baodha-varshta.'

As a parallel for this form of the conditional sentence containing the Indicative and the Subjunctive we may quote Rv. **1**. 161. 8:

yádi tán nḗva háryatha tr̥tī́ytē ghā sávanē mādayādhvāi.

'if ye accept not even this, surely ye shall have your joy at the third pressing.'

A similar condition is presented in Greek by Odyss. **17.** 475–476:

ἀλλ' εἴ που πτωχῶν γε ϑεοὶ καὶ ἐρινύες εἰσίν,
'Αντίνοον πρὸ γάμοιο τέλος ϑανάτοιο κιχείη.

c. Indicative in the Protasis and Optative in the Apodosis.

a. Present tense in both Clauses.

I. The Protasis is introduced by the general relative *ya—:*

ys. **29.** 2 (GAv. verse):

kə̄m hōi uštā ahurəm yə̄ drəġvōdəbīš aēšəməm vādāyōit̰.

'whom do ye will as a lord for her, who (=if one?) might strike down the wrath of the wicked?'

b. Present tense in the Protasis and Aorist tense in the Apodosis.

I. The Protasis is introduced by the general relative *ya—:*

ys. **65.** 14 (yAv. prose):

yat̰ca ahmāt̰ asti mazyō yat̰ca ahmāt̰ asti vaŋhō yat̰ca ahmāt̰ asti srayō yat̰ca ahmāt asti parō-arəjastarəm tat̰ nō dāyata yūžəm yazata.

'what is greater than this, and what is better than this, and what is fairer than this, and what is more precious than this, that ye should give unto us, ye angels!'

A similar condition containing the Indicative and the Optative is found also in the Rig-Veda, e. g., Rv. **9.** 95. 5:

iṅdraśca yát kṣáyathaḥ sáubhagāya suvī́ryasya pátayaḥ syāma.

'if thou and Indra are rulers for weal, we should be lords of manly might.'

As a Greek example we may cite Aischylos Agamemn. 908–909:

> *ἀλλ' εῖ δοκεῖ σοι ταῦθ', ὑπαί τις ἀρβύλας*
> *λύοι τάχος.*

d. Indicative in the Protasis and Injunctive in the Apodosis.

a. Present in the Protasis and Preterite in the Apodosis.

1. The Protasis is introduced by the general relative *ya—:*

vd. **3**. 26 (yAv. prose and verse):

yō imąm ząm aiwi-vərəzyeiti . . .
āat̰ aoxta īm zå : nara . . .

'whoso tilleth this earth, , . . then is the earth to say unto him: O man . . .[1]

2. The Protasis is introduced by *yezi.*

ys. **44**. 15 (GAv. verse):

yezī ahyā ašā pōi mat̰ xšayehī
hyat̰ hə̄m spādā anaocaŋhā jamaētē
avāiš urvātāiš yā tū mazdā dīdərəžō
kuϑrā ayå kahmāi vananąm dadå.

'if thou hast power through Asha over him to ward (him) off from me, when the two hostile hosts shall come together through those doctrines which thou, Mazda, dost desire to have maintained, unto which one of the twain art thou to give the victory?'

e. Indicative in the Protasis and Imperative in the Apodosis.

a. Present tense in both Clauses.

1. The Protasis is introduced by *yeδi, yezi:*

ys. **34**. 6 (GAv. verse):

yezī aϑā stā haiϑīm mazdā ašā vohū manaŋhā
at̰ tat̰ mōi daxštəm dātā.

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[1] With regard to the uses of the Avestan Injunctive, especially where it is precisely equivalent to an Imperative, Subjunctive (as in this passage), Optative, or even Indicative see the discussion to appear in Professor Jackson's forthcoming *Avesta Syntax.*

‘if thus the world indeed (exists), O Mazda, Asha, and Vohu Manah, then give me this sign.’[1]

yt. **16**. 2 (yAv. Prose):

yezi ahi paurva-naēmāṯ āaṯ mąm avi nmānaya: yezi paskāṯ āaṯ mąm avi apaya.

‘if thou art before, then await me; if (thou art) behind, then overtake me.’

The following parallels for this form of the conditional sentence may be cited from the Rig-Veda, the Old Persian, and the Greek.

Rv. **1**. 47.7:

yán nāsatyā parāváti yád vā sthṓ ádhi turaváśē
átō ráthēna suvŕ̥tā na ā́ gataṁ.

‘whether, O true ones twain, ye are afar, or here with Turvaśa, come unto us with well-rolling car.’

Bh. **4**. 37–39:

tuvam kā x[šāyaϑiya] hya aparam ahy hacā draugā daršam patipayauvā mar[tiya hya] draujana ahatiy avam ufrastam parsā yadiy avaϑā ma[niyāhy] dahyāušmaiy duruvā ahatiy.

‘thou who art king hereafter, guard thyself fearfully from the Lie. The men that shall be a liar, punish him well, if thou shalt think thus: May my kingdom be safe!’

(Indicative in Protasis and Imperative in Apodosis. Another conditional clause follows, which has the Subjunctive in the Protasis and the Imperative in the Apodosis. This latter clause is followed in its turn by a Subjunctive in a Protasis without Apodosis and by a Volitative Subjunctive.)

Sophokles Antig. 98:

ἀλλ᾽ εἰ δοκεῖ σοι, στεῖχε.

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[1] Perhaps we might translate: ‘if indeed ye are thus, O Mazda and Asha, through Vohu Manah.’ I have followed, however, the Pahlavi version which renders *stā* by *stī* ‘world’ (Neryosang *ṣṛṣṭi*), and which sees in *Vohū Manaṅhā* an instr. = nom. = voc.

b. Injunctive in the Protasis.

a. Injunctive in both Clauses.

a. Present tense in both Clauses.

1. The Protasis is introduced by the general relative *ya—:*

The appearance of the Injunctive in conditional sentences or indeed in any construction save with the representative of the Indo-Germanic **mḗ* 'not' developed late in the pre-Indo-Germanic period.[1] The usage must have existed even then if we may judge from the Vedic and Avestan languages. The most primitive form of the conditions containing the Injunctive was probably that in which the Injunctive appeared in the strong, or root-aorist. From this Aorist was developed later the imperfect Injunctive (Streitberg Verhand. der 44. Versammlung deutsch. Philol. und Schulmeister 22. Sept., 1897, pp. 165–166).

ys. **32.** 10 (GAv. verse):

hvō mā nā sravå mōrɔndaṯ yɔ̄ acištɔm vaēnaŋhē aogədā
gąm ašibyā hvarəcā yascā dāϑə̄ng drəgvatō dadāṯ.

'this man is to destroy my works who is to call the Cow and sun a most evil thing to be seen with the two eyes, and who is to give gifts unto the wicked.'

b. Aorist tense in both Clauses.

1. The Protasis is introduced by *yezi.*

ys. **53.** 1 (GAv. verse):

vahištā īštiš srāvī zaraϑuštrahē
spitāmahyā yezī hōi dāṯ āyaptā
ašāṯ hacā ahurō mazdå.

'the best wish is to be called Zarathushtra Spitāma's if Ahura Mazda is to give him the boons in accordance with Asha.'

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[1] See Delbrück Vgl. Synt. ii. 352–357, 363–364, 373.

2. The Protasis is introduced by the general relative *ya*—:

ys. **45.** 5 (GAv. verse):

yōi mōi ahmāi sərаošəm dąn cayascā
upā-jimən haurvātā amərətātā.

'whosoever unto this one, even unto me, are to give obedience and teaching, they are to come to Haurvatāt and Ameretāt' (i. e., Salvation and Immortality).

ys. **46.** 13 (GAv. verse):

yə̄ spitāməm zaraϑuštrəm rādaŋhā
marətaēšū xšnāuš hvō nā fərasrūidyāi ərəδwō
aṯ hōi mazdå ahūm dadāṯ ahurō
ahmāi gaēϑå vohū frādaṯ manaŋhā.

'whosoever among mortals is to rejoice Spitāma Zarathushtra by liberality, that man (is) to be reputed upright: then to him Mazda Ahura is to give life; for him is Vohu Manah to prosper herds.'

[Bartholomae Grundriss der iran. Philologie i. 231 regards *xšnāuš* as nom. sg., and not as a verb. See also Jackson Zoroaster 84.]

b. Injunctive in the Protasis and Subjunctive in the Apodosis.

a. Present tense in the Protasis and Aorist tense in the Apodosis.

1. The Protasis is introduced by the general relative *ya*—:

vd. **18.** 29 (yAv. prose):

yasca mē aētahe mərəγahe yaṯ parō-daršahe tanumazō gə̄uš daϑaṯ nōiṯ dim yava azəm yō ahurō mazdå bitīm vāciim paiti-pərəsəmnō bva.

'whosoever is to give to me the body-size of this bird, the Parō-darsha, of meat, never shall I, Ahura Mazda, be questioning him twice.'[1]

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[1] Following the tradition, we might render: 'whosoever is to give to this my bird, the Parō-darsha (cock), its body-size of meat,' etc.

II. REAL CONDITIONS IN THE FUTURE—ANTICIPATORY CONDITIONS.

a. Subjunctive in the Protasis.

a. Subjunctive in Both Clauses.

a. The Present tense in both Clauses.

1. The Protasis is introduced by the general relative *ya—:*

ys. **11**. 5–6 (yAv. verse):

yō mąm taṯ draonō zināṯ vā
trəfyāṯ vā apa vā yāsāiti
yaṯ mē daϑaṯ ahurō mazdå . . .
noiṯ ahmi nmāne zānāite
āϑrava naēδa raϑaēštå . . .
āaṯ ahmi nmāne zayånte
dahakāca mūrakāca.

'whosoever shall take away from me, or shall steal from me, or shall hold back from me that portion which Ahura Mazda gave me, . . . not in this house shall there be born priest or warrior, . . . then in this house shall be born both serpents and vipers (?), etc.'

(Note the variant readings for *zānāite* : *zānaēte* **J 2**. *zānaeti* **H 1**, *zānaite* **Mf 2**. **K 11**. **L 13**, *zanaiti* **J 6**. **7**. **C 1**. **L 1**. **O 2**, *zāinaiti* **Lb 2**.)

ys. **19**. 6 (yAv. prose):

yasca mē aētahmi aŋhvō yaṯ astvainti spitama zaraϑuštra baγąm ahunahe vairyehe marāṯ frā vā marō drənjayāṯ frā vā drənjayō srāvayāṯ frā vā srāvayō yazāite ϑriščiṯ tarō pərətūmciṯ hē urvānəm vahištəm ahūm frapārayeni.

'and whosoever in this material world, O Spitama Zarathushtra, shall recite the portion of the Ahuna Vairya, or reciting it shall pronounce it, or pronouncing it shall chant it, or chanting it shall present it as a sacrifice, thrice I shall bring his soul across the bridge into paradise.'

(Note *marat̰* **J 2**, *mraot̰* **K 5** as variant readings for *marāt̰* and cf. the Indicative *aparaoδayete* and the Subjunctive *tanava* in the similar sentence ys. **19.** 7.)

ys. **31.** 6 (GAv. verse):

ahmāi aŋhat̰ vahištəm yə̄ mōi vīdvå vaocāt̰ haiϑīm
mąϑrəm yim haurvatātō.

'unto him shall be the best thing, whoso wisely shall proclaim for me the true Word of Haurvạtāt.'

(Note *vaocat̰* **K 5. 11. S 1. J 3. 7. 1. H 1. C 1. L 13. 2. 3. Bb 1,** *vaocit̰* **J 6** as variant readings for *vaocāt̰*.)

ys. **46.** 4 (GAv. verse):

yastə̄m xšaϑrāt̰ mazdā mōiϑat̰ jyātə̄uš vā
hvō tə̄ng frō-gå paϑmə̄ng hucistōiš carāt̰.

'whosoever, O Mazda, shall thrust him from kingdom and from life, he shall come proceeding to the paths of good knowledge.'

(Note the variant readings *mōi-ϑāt̰* **P 6** for *mōiϑat̰* and *carat̰* **J 2. 3. 6. 7. Pt 4. S 1. Mf 2. Jp 1. L 13. 2. 3. O 2** for *carāt̰*.

yt. **13.** 18 (yAv. verse):

āat̰ yō nā hīš hubərətå barāt̰
jva ašaonąm fravašayō
sāsta daiŋ́hə̄uš hamō-xšaϑrō
hō aŋhāiti zazuštəmō
xšayō kascit̰ mašyānąm
yō vohu-bərətąm baraite
miϑrəm yim vouru-gaoyaoitīm
arštātəmca frādat̰-gaēϑąm varədat̰-gaēϑąm.

'then whatsoever sovereign ruler of the land while alive shall treat well these Fravashis of the righteous, he shall be a prince most rich in gain whosoever of men (he be), who (=if he) treateth well Mithra, lord of wide pastures, and Arshtāt who maketh the world increase, who maketh the world multiply.'

(Note the variant reading *barat̰* **F 1. Pt 1. E 1. L 18. P 13** for *barāt̰*.)

vd. **7.** 23 (yAv. prose):

kat̰ tā nara yaoždayąn aŋhən ašāum ahura mazda yā nasāum fraŋuharāt̰.

'how shall those men be purified, O righteous Ahura Mazda, who shall eat a corpse.'

(For the number of *fraŋuharāt̰* see Jackson Av. Gramm. § 915.4; note also the variant reading *fraŋharat̰* **Mf 2.** and cf. the Indicative *frabarənti* in the similar sentence in Vd. **7.** 25 above.)

vd. **7.** 36–37 (yAv. prose):

yat̰ aēte yōi mazdayasna baēšazāi fravazånte katārō paurvō āmayånte mazdayasnaēibyō vā daēvayasnaēibyō vā. āat̰ mraot̰ ahurō mazdå daēvayasnaēibyō paurvō āmayayanta yaϑa mazdayasnaēibyascit̰. yat̰ paoirīm daēvayasnō kərəntāt̰ ava hō miryāite yat̰ bitīm daēvayasnō kərəntāt̰ ava hō miryāite . . . anāmātō zī aēšō yavaēca yavaētātaca.

'if these Mazdayasnians shall betake themselves to the healing art, which first shall they try their healing upon, Mazdayasnians or Daēva-worshippers (see Jackson Av. Gramm. § 925 n.)? Then spake Ahura Mazda: They shall try their healing first on the Daēva-worshippers before the Mazdayasnians. If he shall operate first on a Daēva-worshipper and he shall die, if for a second time he shall operate on a Daēva-worshipper and he shall die, . . . he (is) incapable forever and forever more.'

(Note the variant readings *amayaointi* **K1. P1** prim. man. for *āmayånte*, *āmayånta* Injunctive for Subjunctive **Br 1, L1.** In vd. **7.** 39 **Mf 2** once has *kərəntat̰* for *kərəntāt̰*.)

2. The Protasis is introduced by *yedi*, *yezi:*

yt. **19.** 43 (yAv. verse):

yezi bavāni pərənāyu
ząm caxrəm kərənavāne
asmanəm raϑəm kərənavāne.

'if I shall become matured, I shall make the earth my wheel, I shall make the heaven my chariot.'

vd. **3.** 14 (yAv. prose):

yezi šē barāt̰ aēvō yat̰ iristəm upa vā nasuš raeϑwāt̰ nåŋhanat̰ haca cašmanat̰ haca.

'if he shall bear the corpse alone, then the Nasu shall defile him by the nose, by the eye.'

(Note the variant reading *barat̰* **Jp 1. Mf 2. Br 1. Ml 2** for *barāt̰.*)

vd. **6.** 47 (yAv. prose):

yezi nōit̰ didarəzyånte aētaδa hē aēte sūnō vā kərəfš-xᵛarō vayō vā kərefš-xᵛarō aētaŋhąm astąm avi apąmca urvaranąmca barəntəm frajasāt̰.

'if they shall not fasten it down, then either these corpse-eating dogs or corpse-eating birds shall carry some of these bones both to the waters and to the plants.'

vd. **15.** 4 (yAv. prose; cf. vd. **15.** 6):

yezica aēte asti dātāhva arånte garəmōhva vīδånte yat̰ vā aēte garəma xᵛarəϑa stamanəm vā hizvąm vā apa-dažat̰ ahmat̰ haca irišyāt̰. yezi tat̰ paiti irišyeiti aiŋ́hat̰ haca šyaoϑnāvarəza aϑa bavainti pəšō-tanva.

'and if these bones shall get between his teeth, or shall be stuck in his throat, or if this warm food burns his mouth or his tongue, he shall perish from that. Thereupon if he perishes from that, those who did that deed become damned.'

(Note the variant reading *dažāt̰* **Jp 1. Mf 2. L 1. 2. K 10** for *dažat̰*).

b. Present tense in the Protasis and Aorist tense in the Apodosis.

1. The Protasis is introduced by the general relative *ya—:*

ys. **46.** 6 (GAv. verse):

at̰ yastə̄m nōit̰ nā isəmnō āyāt̰
drūjō hvō dāmąn haiϑyā gāt̰.

'then whosoever shall not come when bidden, he shall go unto the true creations of the Druj.'

c. Aorist tense in both Clauses.

1. The Protasis is introduced by *yezi:*

ys. **48.** 1 (GAv. verse):

yezī adāiš ašā drujəm və̄nŋhaitī . . .
aṯ tōi savāiš vahməm vaxšaṯ ahurā.

'if in time to come (? cf. the Pahlavi translation and gloss: *pavan zak dahišnŏ* [*pavan tanŏ ī pasīnŏ*]) Asha shall conquer the Druj, . . . then because of thy mercies the prayer shall increase for thee, O Ahura.'

d. Aorist tense in the Protasis and Present tense in the Apodosis.

1. The Protasis is introduced by the general relative *ya—:*

ys. **45.** 3 (GAv. verse):

yōi īm və̄ nōiṯ iϑā mąϑrəm varəšəntī
yaϑā īm mə̄nāicā vaocacā
aēibyō aŋhə̄uš avōi aŋhaṯ apə̄məm.

'whoso of you shall not do the Word even as I both think and speak it, unto them shall the last day of the world be for the destruction.'

(Note the variant readings *varəšantī* **C 1. K 11. O 2.**, *varəšantē* **Jp 1** for *varəšəntī*. With *avō* here cf. *avaētās* ys. **31.** 20 and see Jackson A Hymn of Zoroaster 54. The tradition regards *mə̄nāi* and *vaoca* as locatives rather than as verbs, but cf. Jackson Av. Gramm. § 651, Bartholomae Grundr. der iran. Philol. 210.)

Here again we find similar forms of the conditional sentence with the Subjunctive in both clauses in Sanskrit, Old Persian, and Greek.

Rv. **2.** 23. 4.

yás túbhyaṁ dā́śān ná tám áṅhō aśnavat.

'whosoever shall serve thee, distress shall not visit him.'

Dar. Pers. e. 22–24.

yadiy kāra pārsa pāta ahatiy hyā duvaiš[*ta*]*m šiyātiš axštā hauvciy aurā nirasātiy abiy imām viϑam.*

'if the Persian folk shall be protected, there shall descend upon this house through the Lord that peace which shall be forevermore.'[1]

Iliad 1. 324.

εἰ δέ κε μὴ δώῃσιν, ἐγὼ δέ κεν αὐτὸς ἕλωμαι.

b. Subjunctive in the Protasis and Indicative in the Apodosis.

a. The Present tense in both Clauses.

1. The Protasis is introduced by the general relative *ya—*:

ys. **54.**1 = **27.**5 (GAv. verse):

yā daēnā vairīm hanāṯ mīždəm
ašahyā yāsā ašīm yąm išyąm ahurō masatā mazdå.

'what (= if any) faith shall merit the wished-for reward, that desirable blessing of Asha I seek which Ahura Mazda is to multiply.'

ys. **62.** 7 (yAv. verse):

vīspaēibyō sastīm baraiti
ātarš mazdå ahurahe
yaēibyō aēm hąm-pacāite
xšāfnīmca sūirīmca.

'unto all doth the Fire of Mazda Ahura bear proclamation, for whom he shall cook the evening and the morning meal' (or 'the repast and the banquet'—see Darmesteter Étud. Iranienn. ii 161–162 as compared with Le Zend-Avesta i 389 n. 24).

(Note the variant reading *pacaiti* **Pt. 4. 1. Mf. 3. Pd. H. 1. 2. P 6. F 1. J 9. K 7c. 15** for *pacāite.*)

yt. 10. 9 (yAv. verse):

yatāra vā dim paurva frāyazāiti
fraorəṯ fraxšni avi manō
zarazdātōiṯ aŋuhyat haca
ātaraϑra fraorisyeiti
miϑrō yō vouru-gaoyaoitiš.

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[1] For other renderings of this crux *hyā duvaiš[ta]m šiyātiš axštā* see Oppert Le peuple . . . des Mèdes 199; Bartholomae Ar. Forsch. ii 100–102, cf. Grundr. der iran. Philol. i 227; Spiegel Altpers. Keilinschr.² 114–115; Foy KZ. XXXV. 49.

'whosoever first shall worship him very zealously in mind, from devotion of the soul, thitherward turneth Mithra, lord of wide pastures.'

(Cf. the Indicative *frāyazənte* in the similar passage yt. **13.** 47.)

vd. 13. 3 (yAv. prose):

yasca dim janat̰ spitama zaraϑuštra spānəm sīždrəm urvīsarəm yim vaŋhāparəm, . . . nava-naptyaēcit̰ hē urvānəm paramərəncaite.

'and whosoever, O Spitama Zarathushtra, shall kill the dog with spiny back (?) and sharp snout (?), Vanhāpara, . . . he doth destroy his soul unto the ninth generation.'

(Cf. the Indicative *jainti* in the similar passage vd. **13.** 8.)

2. The Protasis is introduced by *yeδi, yezi:*

yt. **5.** 63 (yAv. prose and verse):

hazaŋrəm tē azəm zaoϑranąm . . . barāni . . .
yezi jum frapayemi
aoi ząm ahuraδātąm.

'a thousand libations shall I offer thee, . . . if I come alive to this earth created by Ahura.'

yt. **14.** 52–53 (yAv. prose and verse);

yezi šē mairyō gəurvayāt̰ . . .
para baēšaza hacaite
vərəϑraγnō ahuraδātō
hamaϑa airyābyō daiŋ́hubyō vōiγnå jasånti.

'if a bandit shall partake of it, . . . Victory created by Ahura doth draw back his healing might. Continually on the Aryan lands shall come plagues,' etc.

(Note the variant reading of an Optative *gə̄urvayōit̰* **K 38. M 4. Ml 2** for *gəurvayāt̰*.)

vd. **13.** 49 (yAv. prose):

nōit̰ mē nmānəm vīδātō hištənti ząm paiti ahuraδātąm yezi mē nōit̰ åŋhāt̰ spā pasuš-haurvō vā vīšhaurvō vā.

'nor doth a house stand established for me upon the earth created by Ahura, if there shall not be a dog guarding the flock or guarding the village.'

As parallels from the Sanskrit and the Greek for conditional sentences having the Subjunctive and the Indicative we may quote:

Rv. **5.** 4. 11.

yásmāi tváṁ sukŕ̥tē jātavēda u lōkám agnē kr̥ṇávaḥ syōnáṁ
aśvinaṁ sá putríṇaṁ vīrávaṅtaṁ gṓmaṅtaṁ rayíṁ naśatē
svastí.

'for what pious man thou, O Jātavēda Agni, shalt make a pleasant place, he gaineth for his weal wealth of horses, sons, heroes, and kine.'

Euripides Alkestis, 671–672:

ἢν δ' ἐγγὺς ἔλϑῃ ϑάνατος, οὐδεὶς βούλεται
ϑνήσκειν, τὸ γῆρας δ' οὐκέτ' ἔστ' αὐτοῖς βαρύ.

c. Subjunctive in the Protasis and Optative in the Apodosis.

a. The Present tense in both Clauses.

1. The Protasis is introduced by the general relative *ya—*:

ys. **30.** 9 (GAv. verse):

at̰cā tōi vaēm hyāmā yōi īm fərašə̄m kərənāun ahūm.

'and then should we be for thee the ones who [=if any?] may make the world prepared.'

yt. **10.** 91 = ys. **62.** 1 (yAv. verse):

ušta buyāt̰ ahmāi naire
yasə ϑwā bāδa frāyazāite.

'well may it be for that man, who shall continually worship thee.'

yt. **14.** 48 (yAv. prose):

yat̰ mašyāka frāyazą̊nte vərəϑraγnō ahuraδātō . . . nōit̰ iϑra airyą̊ daiŋ́hāvō frąs hyāt̰ haēna nōit̰ vōiγna.

'if men shall worship Victory created by Ahura (cf. Jackson Av. Gramm. § 926 n.), . . . here upon the Aryan lands should come neither horde nor plague.'

(Note the Optatives *aiwisacyārəš* and *frąs hyāṯ* in both Clauses of the similar sentence yt. **8.** 56.)

2. The Protasis is introduced by *yeδi, yezi:*

vd. **16.** 7 (yAv. prose):

yezi apərənāyūkō frāšnavāṯ zasta hē paoirīm frasnāδayən.

'if an infant shall touch her, they should wash his hands first.'

vd. **8.** 3 (yAv. prose);

yezi aētəm nmānəm upa-bərəϑwōtarəm ava-zanąn ava aētəm nmānəm barayən avaϑa iristəm hərəzayən upa aētəm nmānəm baoδayąn.

'if they shall perceive this house more portable, they should bear this house away; they should leave the corpse there: they shall perfume this house.'

(The Subjunctive *baoδayąn* seems to express a command valid in any case, whether the corpse be brought to the dakhma, or the dakhma be built around the corpse.)

vd. **16.** 8 (yAv. prose):

yezi nāirika vohunīš aiwi-vaēnāṯ yaṯ hē ϑrāyō xšafna sacąˊnte airime gātūm hē nišhiδaēta.

'if the woman shall see blood when her three nights shall have elapsed, she should sit in her place of isolation.'

(Note the variant readings Subjunctive for Optative *nišhiδāiti* **Mf. 2.** *nišhaδāita* **Jp. 1.** and Indicative for Optative *nišhaδaiti* **K1a.** *nišhaδaita* **L 4.**)

b. Present tense in the Protasis and Aorist tense in the Apodosis.

1. The Protasis is introduced by the general relative *ya—:*

ys. **68.** 10–12 (yAv. prose):

yō vō āpō vaŋuhīš yazāite . . . ahmāi vahištəm ahūm ašaonąm raocaŋhəm vīspō-x^{v}*āϑrəm dāyata vaŋuhīš āpō.*

'whosoever of you shall worship the good waters, . . . unto him should ye give, O good waters, the best life of the righteous, radiant, all-glorious.'

The following are examples of conditional sentences in Sanskrit, Old Persian, and Greek, which have the Subjunctive in the Protasis and the Optative in the Apodosis.

Rv. **4**. 41.11:

yád didyávaḥ pŕ̥tanāsu prakrīḷān tásya vāṁ syāma sanitā́ra ājéḥ.

'when the arrows shall play amid the battles, we should be victors of that booty.'

Bh. **4**. 54–56:

yadiy imām haḍugām naiy apagaudayāhy kārahyā ϑāhy auramazdā ϑuvām dauštā biyā u[tātaiy taumā] vasiy biyā utā dargam jivā.

'if thou shalt not conceal this edict, (but) shalt tell it to the people, Auramazda should be thy friend, and thy family should be many, and thou shalt live long.'[1]

Aristophanes Nephel. 116–118.

ἢν οὖν μάθῃς μοι τὸν ἄδικον τοῦτον λόγον,
ἃ νῦν ὀφείλω διὰ σέ, τούτων τῶν χρεῶν,
οὐκ ἂν ἀποδοίην οὐδ᾽ ἂν ὀβελὸν ὀυδενί.

d. Subjunctive in the Protasis and Injunctive in the Apodosis.

a. *The Present tense in both Clauses.*

1. The Protasis is introduced by the general relative *ya*—:

yt. **11**. 4–5 (yAv. prose):

yasca zaraϑuštra imaṯ uxδəm vacō fravaocāṯ . . . nōiṯ dim yava . . . drvå . . . aoi ava-spašnaoṯ.

'whosoever, O Zarathushtra, shall pronounce this spoken word . . . never him . . . is the wicked man . . . to spy.'

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[1] On *jivā* as a Subjunctive see Bartholomae ZDMG. XLVI. 295, and Grundr. der iran. Philol. i. 201. This view is sustained by the Precative in the Babylonian version (l. 102) *ūmēka līrikū*. Cf. also the Elamitic rendering *takataktine* and see Weisbach Achämeniden-inschriften zweit. Art. 52 and Foy ZDMG. LII. 580 Anm. 4, 582.

2. The Protasis is introduced by *yezi:*

vd. **5**. 14 (yAv. prose):

yezi nōit̰ aēte mazdayasna aētəm kəhrpəm hvarə-darəsīm kərənavąn yārə-drājō avavantəm ašavaγnyāi tąm ciϑąm daēsayō.

‘if these Mazdayasnians shall not make this corpse beheld by the sun for the length of a year, thou art to teach so great a penalty as for the murder of a righteous man.’

vd. **7**. 12 (cf. vd. **7**. 13) (yAv. prose):

yezi aŋhat̰ upaētəm vā aiwi-naptīm vā aiwi-iritīm vā aiwi-vantīm vā aētaδa hē aēte mazdayasna aētå vastrå fraca kərəntən nica kaṇayən.

‘if it shall be stained with either semen, or matter, or ordure, or vomit, then are these Mazdayasnians to tear up these garments, and they should bury them.’

(In this last example the use of the Optative *kaṇayən* beside the Injunctive *kərəntən* is noteworthy. On the other hand, the lateness of the passage should warn us against pressing too strongly the fundamental distinctions between the two moods.)

As an example of the conditional sentence having the Subjunctive in the Protasis, and the Injunctive in the Apodosis in the Rig-Veda we may cite Rv. **4**. 30. 23:

utá nūnám̐ yád indriyám̐ kariṣyā́ indra pā́uṅsyam
adyā́ nákiṣ ṭád ā́ minat.

‘and now whatever heroic, manly deed thou shalt perform, O Indra, that no one is to minish to-day.’

e. Subjunctive in the Protasis and no finite form of the verb in the Apodosis.

a. *Present tense in the Protasis.*

1. The Protasis is introduced by *yezi:*

vd. **5**. 4 (similarly also vd. **5**. 7, cf. vd. **8**. 34) (yAv. prose):

yezica aēte nasāvō . . . narəm āstryeintīm åṅhāt̰ išarə-štāitya mē vīspō aŋhuš astvå išasəm jit̰-ašəm xraodat̰-urva pəšō-tanuš.

‘and if these corpses . . . shall defile man, straightway (will or would be) all my material world desiring the destruction of righteousness, with hardened soul, and damned.’

B. IDEAL CONDITIONS.

Optative in the Protasis.

I. Ideal Conditions in the Future-Possible Conditions.

a. Optative in both Clauses.

a. The Present tense in both Clauses.

1. The Protasis is introduced by the general relative *ya—:*

ys **43.** 3 (GAv. verse):

at̰ hvō vaŋhə̄uš vahyō nā aibī-jamyāt̰
yə̄ nå ərəzūš savaŋhō paϑō sīšōit̰.

'then should this man come unto what is better than good, who justly should teach the pathways of weal.'

ys. **50.** 2 (GAv. verse):

kaϑā mazdā rānyō-skərətīm gąm išasōit̰
yə̄ hīm ahmāi vāstravaitīm stōi usyāt̰.

'how, O Mazda, should one desire the Cow joy-giving? whosoever (= if any one) should wish her (to be) well pastured for this world.'[1]

b. Present tense in the Protasis and Perfect tense in the Apodosis.

1. The Protasis is introduced by *yeδi:*

yt. **8.** 11 = yt. **10.** 55 and 74 (yAv. prose and verse):

yeδi zī mā mašyāka aoxtō-nāmana yasna yazayanta . . .
fra nəruyō ašavaoyō
ϑwarštahe zrū āyu šušuyąm . . .
upa ϑwarštahe jaγmyąm.

'if indeed men should honor me with worship in which my name is mentioned, . . . forth would I be arrived at the appointed time for the righteous men, . . . forth would I be come at the appointed time'.

(Note the variant reading *yazinti* **J 10** for *yazayanta.*)

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[1] If we depart from the tradition, we may also render: 'how, O Mazda, should he desire the Cow joy-giving, who should wish her (to be) well pastured for this world?'

b. Optative in the Protasis and Indicative in the Apodosis.

a. The Present tense in both Clauses.

1. The Protasis is introduced by *yezi:*

vd. **6**. 4 (yAv. prose):

yezi mazdayasna tąm ząm kārayən yezi āpō hərəzayən yaṯ ahmi spānasca narasca para-iriϑinti antarāṯ naēmāṯ yārə-drājō kā hē asti ciϑa.

'If the Mazdayasnians should cultivate that land, if they should let the waters flow where either dogs or men perish within the course of a year, what is the penalty?'

For similar conditions with the Optative in the Protasis and the Indicative in the Apodosis in Sanskrit and Greek we may cite the following:

Rv. **5**. 74. 10:

áśvinā yád dha kárhi cic chuśrūyā́tam imáṁ hávam
vásvīr ū ṣú vāṁ bhújaḥ pr̥ṅcánti sú vāṁ pŕ̥caḥ.

'O Aśvins, if at any time ye should hear this prayer, your benefits, good indeed, prepare delights for you.'

Iliad **10**. 222–223:

ἀλλ᾽ εἴ τίς μοι ἀνὴρ ἅμ᾽ ἕποιτο καὶ ἄλλος,
μᾶλλον θαλπωρὴ καὶ θαρσαλεώτερον ἔσται.

c. Optative in the Protasis and Subjunctive in the Apodosis.

a. The Present tense in both Clauses.

1. The Protasis is introduced by the general relative *ya—:*

ys. **50**. 3 (GAv. verse):

aṯcīṯ ahmāi mazdā ašā aŋhaitī
yąm hōi xšaϑrā vohucā cōišt manaŋhā
yə̄ nā ašōiš aojaŋhā varədayaētā
yąm nazdištąm gaēϑąm drəgvå baxšaitī.

'Then indeed, O Mazda, shall he have (the Cow), which the Kingdom and the Good Mind promised, whosoever through the strength of piety should increase the nearest land which the wicked man doth share.'

ys. **10**. 8 (yAv. verse):

yō yaϑa puϑrəm taurunəm
haoməm vandāeta mašyō
frā ābyō tanubyō
haomō vīsāite baēšazāi.

'whatever man should welcome Haoma even as a tender son, Haoma shall come unto their bodies for healing.'

(Note the variant readings *vəndaita*, **B 3. M 1**, *vandaiti* **L 13. Lb 2. K 11. Bb 1** for *vandaēta*, and *vīsaēte* **Pt 4**, *vīsaite* **J 3. Mf 2** *vīsaiti* **K 4. J 6. 7. H 1. P 6. C 1. L 2. 3. O 2. Bb 1**, *vīsaita* **L 13** for *vīs āite*).

2. The Protasis is introduced by *yeδi, yezi:*

vd. **6**. 3 (yAv. prose):

yezi mazdayasna tąm ząm kārayən yezi āpō hərəzayən yaṯ ahmi spānasca narasca para-iriϑinti antarāṯ naēmāṯ yārə-drājō nasuspaēm pascaēta āstryånte aēte yōi mazdayasna apasca zəmasca urvarayåssca.

'if the Mazdayasnians should cultivate that land, if they should let the waters flow, where either dogs or men perish within the course of a year, then shall these Mazdayasnians defile with corpse-burial both waters, and lands, and plants.'

(Cf. the Optative and Indicative in the similar passage vd. **6**. 4 and the Subjunctive and Indicative in vd. **6**. 8. It is also interesting to observe the implied remoteness of the possibility of such a defilement, as contrasted with the positive future certainty of the penalty if the defilement is committed.—Professor Jackson.)

vd. **9**. 47 (yAv. prose):

yezica hō nā paiti-hincōiṯ yō nōiṯ apivatāite daēnayå māzdayasnōiš yaoždāϑryāṯ haca kuϑa aētaṯ druxš pərənāite yā haca irista upa jvantəm upa-dvąsaite kuϑa aētaṯ nasu pərənāite yā haca irista upa jvantəm upa-raēϑwayeiti.

'and if this man should sprinkle who should not be cognizant of the Mazdayasnian religion in accordance with purification, how then shall that Druj be combated, who pounceth from the dead onto the living, how then shall that Nasu be combated, who mingleth from the dead onto the living?'

(Note the variant reading *apavaiti* **Mf. 2.** for *apivatāite.*)

b. Aorist tense in the Protasis and Present tense in the Apodosis.

1. The Protasis is introduced by the general relative *ya*:—

ys. **46.** 10 (GAv. verse):

yə̄ vā mōi nā zənā vā mazdā ahurā
dāyāṯ aŋhə̄uš yā tū vōistā vahištā . . .
frō tāiš vīspāiš cinvatō frafrā pərətūm.

'whosoever, either man or woman, should give me in this world what thou, O Mazda Ahura, dost deem best, . . . forth with them all I shall come unto the Cinvat-bridge.'

The conditional sentence containing the Optative in the Protasis and the Subjunctive in the Apodosis is not absolutely unknown to the Sanskrit, although examples are very rare. As a possible instance we may cite Rv. **8.** 40.1:

indrāgnī yuváṁ sú naḥ sáh aṅta dā́sathō rayiṁ
yēna dṛḷhā́ samátsvā́ vīḷú cit sāhiṣimáhi.

'Indra and Agni, mighty ones, ye shall give wealth to us, whereby (= if by it?) we should gain what is fixed and fast.'

II. Ideal Conditions in the Past—Unfulfilled Conditions.

a. Optative in both Clauses.

a. The Present Tense in both Clauses.

1. The Protasis is introduced by *yeδi:*

yt. **8.** 52–54 (yAv. prose and verse):

yeδi zī azəm nōiṯ daiδyąm spitama zaraϑuštra aom stārəm yim tištrīm . . .

hamahe zī mē iδa ayąn hamayå vā xšapō
xå pairika yā dužyāirya
vīspahe aŋhə̄uš astvatō

parōiṯ pairiϑnəm aŋhvąm ava-hisiδyāṯ
āca paraca dvaraiti.

'if indeed I should not have created, O Spitama Zarathushtra, that star Tishtrya, . . . verily all the day and all the night this Pairika Duzhyāirya would seem (?) a bond (?) before the life (?) of this material world, (as), she rusheth to and fro.'[1]

yt. **13.** 12–13 (yAv. prose and verse):

yeiδi zī mē nōiṯ daiδīṯ upastąm uγrå aṡāunąm fravašayō nōiṯ mē iδa

åŋhātəm pasvīra
yā stō sarəδanąm vahišta
drujō aogarə drujō xšaϑrəm
drujō astvå aŋhuš åŋhāṯ . . .
hazdyāṯ . . . vaonyāṯ . . . upą-dayāṯ.

'if indeed the awful Fravashis of the righteous should not have given me aid, then I shall not have cattle or men, which are the two best things of the kind; the power will belong to the Druj, the kingdom will belong to the Druj, the material world will belong to the Druj, . . . would use violence, . . . would conquer, . . . would yield.'

(The interchange of the Optatives *hazdyāṯ*, *vaonyāṯ*, and *upa-dayāṯ* with the Perfect Subjunctives *åŋhāṯ* and *åŋhātəm* has already been noted by Bartholomae Altiran. Verb. 189–190. The general sense of the passage seems to be an Unfulfilled rather than a Possible Condition.)

b. Optative in the Protasis and Subjunctive in the Apodosis.

a. The Present tense in both Clauses.

1. The Protasis is introduced by *yeiδi:*

vd. **1.** 1 (yAv. prose):

yeiδi zī azəm nōiṯ daiδyąm spitama zaraϑuštra asō rāmō-dāitīm nōiṯ kudaṯ šāitīm vīspō aŋhuš astvå airyanəm vaējō frāšnvāṯ.

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[1] Professor Jackson suggests that *hisiδyāt* may be a reduplicated form of the Av. √*sad*, Old P. √*ϑad* 'seem,' and that *pairϑna* may be from the √*tan* 'stretch' +*paiti*. The genitive *aṅhvam* would then be governed by the preposition *parōit*.

'if I should not have created, O Spitama Zarathushtra, a place joy-giving, (although really) not pleasant anywhere, all the material world will come to Irān Vēj.'

(For this strange use of the Subjunctive, apparently due to the loss of feeling for the finer mood-distinctions, compare the interchange of the moods in the preceding example.)

As examples of the conditional sentence containing the Optative in both clauses in Sanskrit and Greek we may cite the following passages:

Rv. **8.** 44.23

> *yád agnē syā́m ahám̐ tvám̐ tvám̐ vá ghā syā́ ahám̐*
> *syúṣ ṭē satyā́ ihā́śiṣaḥ.*

'if I should be thou, Agni, or thou shouldst be I, thy wishes should come true.'

Iliad **7.** 28:

> ἀλλ᾽ εἴ μοί τι πίθοιο, τό κεν πολὺ κέρδιον εἴη.

In the case of the Condition of Unfulfilled Ideality the Greek has made an innovation on the Indo-Germanic form by substituting the Indicative for the Optative. This change renders the sentence more vivid, since it brings to the front the actual state caused by the actual unfulfillment of the condition. Cf. for example Iliad **5.** 679–680:

> καί νύ κ᾽ ἔτι πλέονας Λυκίων κτάνε δῖος Ὀδυσσεύς,
> εἰ μὴ ἄρ᾽ ὀξὺ νόησε μέγας κορυθαίολος Ἕκτωρ.

Yet in the Greek we find relics of the more primitive construction. For example, we have the Optative in the Apodosis of an Unreal Condition in Iliad **2.** 80–81:

> εἰ μέν τις τὸν ὄνειρον Ἀχαιῶν ἄλλος ἔνισπεν,
> ψεῦδός κεν φαῖμεν καὶ νοσφιζοίμεθα μᾶλλον.

Cases are not wanting of the original form of this condition with the Optative in both Clauses, as we see in Iliad **23.** 274–275.

> εἰ μὲν νῦν ἐπὶ ἄλλῳ ἀεθλεύοιμεν Ἀχαιοί,
> ἦ τ᾽ ἂν ἐγὼ τὰ πρῶτα λαβὼν κλισίηνδε φεροίμην.

The Latin stands nearer to the Indo-Germanic syntax in this form of the conditional sentence than the Greek, *e. g.*, Cicero, de Senect. 11:

quae si exequi nequirem, tamen me lectulus oblectaret meus.

In like manner we find the Subjunctive and not the Indicative in Unfulfilled Conditions in Germanic, *e. g.*, Otfrid **2.** 3.46:

thaz éina uuâri uns núzzi, hábêtîn uuir thie uuizzî.

'that one thing were good for us, had we that knowledge' (cf. also Erdmann, Untersuchungen über die Synt. der Sprache Otfrids i. 108–111).

C. DEFECTIVE CONDITIONS.

Under this rubric we may place those conditional sentences whose Protasis contains no finite form of the verb. Such sentences are 'defective' in so far as they cannot be classified under any of the classes already discussed, since we have seen that the verb of the Protasis determines the class to which a conditional sentence belongs. The omitted verb in Indo-Iranian as well as in Indo-Germanic is generally the copula *as* 'to be.' The following examples from the Avesta may serve to illustrate the Defective Condition.

a. Indicative in the Apodosis.

ys. **31.** 2 (GAv. verse):

yezī āiš nōiṯ urvānē advå aibī-dərəštā vahyå
aṯ vå vīspəng āyōi yaϑā ratūm ahurō vaēdā.

'if through these things the better path for the soul (is) not in sight, then I come to you all, as Ahura knows the judge.' (For *aibī-dərəštā* as locative cf. the Pahlavi translation *madam nikēzisnīh*, similarly also ys. **50.** 5. See further, Jackson, A Hymn of Zoroaster, 22–24).

b. Subjunctive in the Apodosis.

yt. **10**. 19 (yAv. verse):

ahmāi naēmāi uzjasāiti
miϑrō gıantō upa-ṯbištō
yahmāi naēmanąm miϑrō-druxš
naēδa mainyu paiti-pāite.

'unto that side shall Mithra proceed, angry (and) displeased, on which side (is) the Mithra-druj, neither shall he protect himself against the two spirits.'

A similar Defective Condition having the Imperative in the Apodosis is found in Rv. **1**. 14. 8:

yḗ yájatrā yá ī́ḍyās tḗ tē pibaṅtu jihváyā.

'whosoever (are) to be honored or (are) to be praised, let them drink with thy tongue.'

A similar omission of the verb in the Protasis is very common in the younger Avestan when the Protasis is introduced by the formula *yezi nōiṯ* 'otherwise.' This Avestan phenomenon is precisely the same as the Greek usage with εἰ δὲ μή.

a. Subjunctive in the Apodosis.

vd. **13**. 31 (yAv. prose):

yezi nōiṯ spā avacå vā aδāityō-xratuš pasūm vā narəm vā raēšyāṯ para hē irišintō' raēšəm cikayaṯ baoδō-varštahe ciϑaya.

'otherwise the dog without giving voice or being mad shall wound either beast or man. One shall atone for the wound of the injured man with the atonement of a Baodha-varshta.'

(Note the thematic Subjunctive *cikayāṯ* found as a variant reading for the Subjunctive *cikayaṯ*—Jackson, Av. Gramm. § 551—in **K1. Mf 2**.)

b. Optative in the Apodosis.

vd. **16**. 2, 7 (yAv. prose):

yezi nōiṯ nāirika ātrem aiwi-vaēnāṯ yezi nōiṯ nāirika āϑre raoxšnąn paiti-diδyāṯ . . . yezi nōiṯ nāirika niuruiδyāṯ.

'otherwise the woman shall see the fire, otherwise the woman would behold the light of the fire . . . otherwise the woman would grow too weak' (cf. Darmesteter, Le Zend-Avesta Trad. ii. 232 n. 11 for this last word. The interchange here between the Subjunctive *aiwi-vaēnāt̰* and the following Optatives is a mark of the lateness of this particular passage.)

c. Imperative in the Apodosis.

vd. 8. 17 (yAv. prose):

yezi nōit̰ upa vī spitama zaraϑuštra spānəm zairitəm caϑru-cašməm nōit̰ spaētəm zairi-gaošəm xšvažayacit̰ taδa aētå paϑå vīvāδayantu.

'otherwise let them cause to go six times along these ways, O Spitama Zarathushtra a yellow dog with four eyes, or a white one with yellow ears.'

As an example of a similar Defective Condition in Greek we may cite Aristophanes, Nephel. 1433:

πρὸς ταῦτα μὴ τύπτ'· εἰ δὲ μή, σαυτόν ποτ' αἰτιάσει.

Instances are not lacking in the Avesta of conditional sentences which are not introduced by any conditional particle or pronoun whatsoever. As an example we may cite:

vd. 5. 1–2 (yAv. prose):

nā tat̰ para-iriϑyeiti avi jąfnavō raonąm ā tat̰ mərəγəm uz-vazaite haca barəšnavō gairinąm avi jąfnavō raonąm. . . . nā tat̰ frašusaiti haca jąfnavō raonąm avi barəšnavō gairinąm upa tąm vanąm aēiti yąm hō mərəγō āϑre aēsmąn išaiti . . . kā hē asti ciϑa.

'a man perishes in the depths of the valleys; a bird goes from the heights of the mountains to the depths of the valleys; . . . a man proceeds from the depths of the valleys to the heights of the mountains; he comes to that tree where the bird is; he wishes fuel for the fire; . . . what is his penalty?'

The same type of sentence is found in other languages as well. Cf. for instance a Latin example, where conditions with and without a conditional particle stand side by side, in Juvenal, 3. 100–101:

rides, maiore cachinno
concutitur; flet; si lacrimas adspexit amici.

With regard to the tenses of the Subjunctive, Optative, and Injunctive in the conditional sentences of the Avesta, I have not been able to detect any difference in force between the Present and the Aorist. The distinction which exists in some languages, such as Greek, between the Aorist and the Present seems to be entirely lacking in Avestan. This is the same conclusion as was reached by Jolly in 1872 (Conj. u. Opt. 20–21).

Variations in mood in the same verb when it is repeated in a parallel passage or in different manuscripts of the same passage are rather frequent. The following examples may be collected from the texts considered above.

A. Indicative beside Subjunctive: *frīnaiti* ys. **62.** 9: *āfrīnāṯ* vd. **18.** 26, *zānāite* ys. **11.** 6: *zānaite* **Mf 2. K. 11. L 13**, *zānaiti* **J 6. 7. C 1. L 1. O 2**, *marāṯ* ys. **19.** 6 **Pt 4. S 1. Mf 1. 2. K 4. Bb 1**: *maraṯ* **J. 2**, *vaocāṯ* ys. **31.** 6 **J 2. Pt 4. Mf 1. 2. Jp. 1. K 4. 37. Pd. L 1. Dh 1. S 2**: *vaocaṯ* **K 5. 11. S. 1. J 3. 7. 1. H 1. C 1. L 13. 2. 3. Bb 1**, *carāṯ* ys. **46.** 4 **K 4. 10. Jm. 1. L 1**: *caraṯ* **J 2. 3. 6. 7. Pt. 4. S 1. Mf 2. Jp. 1. L. 13. 2. 3. O 2**, *barāṯ* yt. **13.** 18 **Mf 3. K 13. 14. 38. Lb. 5. H 5. J 10**: *baraṯ* **F 1. Pt 1. E 1. L 18. P 13.** (cf. vd. **13.** 14), *hąm-pacāite* ys. **62.** 7 **Pt 4. 1. Mf. 3. Pd. H 1. P 6. Mf 1. Jp 1. K 4. 36. J 9. H 2. J 2. K 5. J 15**: *hąm-pacaiti* **Pt 4. 1. Mf. 3. Pd. H 1. 2. P 6. F 1. J 9. K 7c. 15.**

B. Optative beside Subjunctive: *gəurvayāṯ* yt. **14.** 52 **F 1. E 1. K 16. Jm 4. L 11. Pt. 1. L 18. P 13. O 3**: *gə̄urvayōiṯ* **K 38. M. 1. Ml 2**, *nišhiδāiti* vd. **16.** 8 **Mf 2** and *nišhaδāita* **Jp 1** and Indicatives *nišhaδaiti* **K 1a** and *nišhaδaita* **L 4**: *nišhiδaēta* **L 2. Br. 1. L 1. K 10**, *vīsāite* ys. **10.** 8 **M 1. J 2**, and Indicatives *vīsaite* **J 3. Mf 2** and *vīsaiti* **K 4. J 6. 7. H 1. P 6. C 1. L 2. 3. O 2. Bb 1**: *vīsaēte* **Pt. 4.**

A somewhat similar phenomenon is the use of different modes in the Apodoses of a single Protasis. Thus in the Apodoses of the conditional sentence in Vd. **18.** 69–70 we find in one the Subjunctive *frāvinuyāṯ* and in the other the Optative *frabarōiṯ*. The lateness of the passage arouses one's suspicion. It is to be inferred from the passages which we have cited that the Subjunctive and Indicative are most liable to be interchanged. The possible ground for this is the fact that the Subjunctive and the indicative are the most vivid moods. On the other hand, the majority of these interchanges between the Subjunctive and the Indicative are certainly only apparent. They are due to the frequent confusion in the Avestan manuscripts of the signs for *ă* and *ā* (compare on this Jackson, Av. Gram., § 18, note 1). It is noteworthy that an interchange between the Optative and Indicative is scarcely found without some of the manuscripts showing a Subjunctive as well. Especial emphasis is to be laid on the fact that the older the Avestan texts are, the more accurate are the distinctions in the use of the moods. Thus we find that the Gāthās are the most exact in their use of Indicative, Subjunctive, Optative, and Injunctive, while in certain portions of the Vendidād a confusion reigns which is almost hopeless, so far had the feeling for the language decayed.

Conclusion.—In the light of the examples which have been given in discussing the problem of the conditional sentences in Avestan, one important fact becomes clear. This fact is that the conditions are capable of exact classification, and that their types are as clearly defined as are those of the conditional sentences of Sanskrit or of Greek. More than this, we see that the types of the conditional sentences in Avestan are quite the same as those which meet us in the Vedic language, and that in one instance—the Unfulfilled Condition—the Avestan type is older than the Greek. The inference which is to be drawn from these proofs of the antiquity of the Avestan syntax in regard to the conditional sentences is the necessity of emphasizing the importance of a strict adherence in the interpretation of the Avestan texts to the laws of the great body of Indo-Germanic syntax.

Columbia University,
March, 1899.

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[Zoology of Puget Sound, Columbia University Contributions No. 12.]

SOME ASCIDIANS FROM PUGET SOUND, COLLECTIONS OF 1896.

Wm. E. Ritter.

(Read November 14, 1898.)

[Plates XVIII.–XX.]

The collection of Ascidians made by the Zoological Expedition of Columbia University to Puget Sound during the summer of 1896, and placed in my hands for study, contains, according to the determinations that I am now able to make, fifteen species, seven of which are new to science.

Dr. Bashford Dean, who collected the Ascidians, did so with the design of describing the new species himself, and to this end made colored figures from life of several of the species. Upon learning that I was, and had been for some years, engaged upon the preparation of a monograph of the Tunicata of the Pacific coast of North America, he very willingly and kindly turned over to me not only his material, but also his figures. Hence it is that I am able to report on this interesting, though small, and in the case of some of the forms, quite defective, collection; hence it is, also, that I am able to enrich several of the descriptions by excellent colored figures from life.

I wish to acknowledge here my obligation to one of my students, Miss Edith Byxbee for the excellent and extended aid she has given me in this research. The greater part of the work on the simple Ascidians is hers.

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DESCRIPTIONS OF SPECIES.

Cynthia superba n. sp.

(Pl. XVIII., Fig. 1, Pl. XIX., Figs. 16, 17, 18 and 20, and Pl. XX., Fig. 19.)

General Appearance: Body regularly pear-shaped; the broad end at the base. Attached by the base, but the area of attachment not extending over the entire base. A rather prominent knob and numerous short, closely interwoven root-like processes on this area. Siphons prominent, the branchial bent over so that the orifice looks ventrad; atrial directed upward. External surface of body entirely free from wrinkles or other irregularities, but closely set with very fine short papillæ. Color of the anterior half bright orange red; the posterior half yellowish white. Length 15 cm.; diameter in thickest part 6.5 cm.; in smallest part 4.5 cm.; transverse section of body at any level almost a perfect circle.

TEST: Leathery, about 1 mm. thick and very uniform throughout. Surface closely beset with short, conical, acute processes, the bases of which are nearly equal in thickness to the height; many of these processes are single, but others have one or several smaller ones arising from their bases (Pl. XIX, Fig. 16).

MANTLE: Moderately developed, not quite as thick as the test; longitudinal and circular muscle layers about equal in thickness; the longitudinal fibers somewhat stronger and arranged in bands more distinctly than the circular fibers.

BRANCHIAL APPARATUS: Siphons prominent, strong, branchial bent over to nearly a right angle with the antero-posterior axis of the body; atrial nearly erect, the two of about equal size; branchial distinctly four-lobed, atrial two-lobed. Atrial orifice surrounded by a row of processes similar to but distinctly larger than those covering the entire surface of the test. Branchial tentacles very large, about 18 in number, 13 large ones with smaller ones scattered irregularly among the larger, grouped somewhat in the region of the dorsal tubercle. The numerous large branches of the tentacles themselves bearing short secondary branches, or processes (Pl. XIX., Fig. 20). Dorsal tubercle conspicuous; mouth of the hypophyseal duct with long horns produced into a double, inturned spiral, one horn with four turns, the other with about six (Pl. XIX., Fig. 17). Branchial sac with nine folds on each side, each having sixteen to eighteen bars; from three to five, usually four, bars between the folds; transverse vessels of four sizes, usually arranged in the following manner: the space between two vessels of the first order is divided into two parts by a vessel of the second order; each of these spaces is again divided by a vessel of the third order, and each of these four last spaces is crossed by a vessel of the fourth order; so that between two of the broad vessels of the first order there are seven smaller vessels. The meshes contain about eight to sixteen stigmata each. The whole structure of the sac rather irregular (Plate XIX., Fig. 18). Dorsal languets consisting of a row of large, closely placed ones situated along the right margin of a broad dorsal area in which there are no stigmata; and of numerous smaller accessory ones scattered irregularly over the area to the left of the row of large ones (Pl. XX., Fig. 19).

INTESTINE: Forming a wide loop on the left side of the body; œsophageal opening about midway on the dorsal line of the branchial sac.

REPRODUCTIVE GLANDS: Situated on both sides of the body, very voluminous, particularly on the left side in the intestinal loop.

The collection contains but a single specimen of this magnificent species, so the study of it has been less complete than could be desired. (For comparison with other species, see discussion following description of the next species.)

Cynthia deani n. sp.

(Pl. XVIII., Figs. 2 and 3; and Pl. XIX., Figs 21, 22, and 23.)

GENERAL APPEARANCE: Body oval, tapering gradually toward the posterior end, where it is attached by a clump of root-like processes of the test. Siphons placed at the anterior end, usually prominent, though the branchial is sometimes on a level with the body, apparently owing to contraction. Branchial siphon four-lobed, bent over so that the orifice looks ventrad; atrial siphon two-lobed, directed straight forward; color of specimens preserved in formalin, a dull white, or light gray, the anterior part, and especially the siphons, tinged with orange-red.

TEST: Thin, coriaceous; in young specimens almost transparent; covered with papillæ, each bearing a number of short spines which, in the youngest (smallest) specimens, are regularly arranged in circles, with a larger spine in the center. This regular arrangement disappears in older specimens. The spines imparting to the test a harsh feeling (Pl. XIX., Fig. 21).

MANTLE: Thin, muscles well developed, especially the longitudinal ones.

BRANCHIAL SAC: Nine folds on each side in well developed specimens, eight of them strong, the ones next the endostyle on each side weak, sometimes disappearing before reaching the anterior end of the sac; six to ten bars on the folds, usually only about three between them, this number varying from one to five according to the size of the individual; folds ending abruptly at the œsophageal opening where the bars are prolonged in the form of languets; transverse vessels of at least three sizes, usually six narrow ones between two broad ones. Meshes oblong, crossed by delicate secondary vessels. Stigmata six to twelve in a mesh, small and narrow; a longitudinal vessel often running part way down the branchial sac and so forming smaller, square meshes (Pl. XIX., Fig. 22).

TENTACLES: About twenty-four in number, twelve large, very stout ones, twice branched, and as many small ones alternating with them (Pl. XIX., Fig. 23).

Peritubercular area shallow; dorsal tubercle large; mouth of hypophysis with its horns turned in and twice coiled.

DORSAL LAMINA composed of languets, short at the anterior end and passing part way round the opening of the œsophagus. No basal membrane present; transverse vessels on the right side ending in languets opposite the dorsal languets, and in the larger specimens, a few small accessory languets present between these two rows (Pl. XIX., Fig. 23).

ENDOSTYLE very broad.

INTESTINE: Making a wide loop; œsophageal opening about half way between the anterior and posterior extremities of the branchial sac; liver large.

OVARIES: One on each side of the branchial sac, in the form of a slender tube bent like the letter S lying down. The genital duct directed upward; endocarps present on the mantle.

There are two specimens of this species in the collection, both small and apparently young. One measures 2.6 × 1 cm., the other 5 × 2.3 cm. The color of the test seems to be well preserved. The above description is based partly on these two specimens and partly on a number from the Young Naturalists' Society of Seattle. The latter are preserved in alcohol and their test is colorless. It is also thicker and lacks the semi-transparency characteristic of the test of the Columbia specimens. The largest one in the Young Naturalists' collection measures 5 × 2 cm. and the genital organs are perfectly developed.

Some of the characters, such as the number of bars on or between the folds and the number of the accessory languets, are variable, but the variation seems to be in the direction of increase of number with increase in the size of the individual.

There are so many points in common between this species and *C. superba* that I have been in much doubt as to whether they are not the same thing. It has seemed possible that the smaller animals may be only immature individuals of the larger one. I have tried to explain the differences between the two by imagining them to be such as would be expected were this the case; but the explanations thus reached are unsatisfactory, as I shall now attempt to show.

In the first place, as regards the papillæ on the surface of the test. These are frequently single in *C. superba*, while they are never so in *C. deani*; again, when the large ones have smaller ones about their bases, these smaller ones are always closer to the larger, and less numerous in the former than in the latter species. Compare figures 16 and 21, the first from the anterior part of the body of *C. superba*, the last from a corresponding region of *C. deani*. These differences I do not believe are due to differences in age merely. One might imagine that the condition seen in *C. superba* has been produced from that in *C. deani* by an extension and thickening of the bases of the primary papillæ until they have come to carry the secondary ones on their sides. As a matter of fact, however, the base of a group, *i. e.*, of a primary papilla with its surrounding secondary ones, is actually somewhat larger on the average in *C. deani*, the supposed younger specimens, than in *C. superba*. Thus their average diameter at base is 1.9 μ in the former species, and 1.55 μ in the latter, measurements being made of papillæ from near the anterior end of the animal in each case.

As to external characters, it is to be further noted that *C. superba* is much more highly colored than *C. deani*, the entire anterior half of the former being orange red, while only the siphons are red in the latter, and these not markedly so. As all the specimens in this collection were preserved in the same way, *i. e.*, in formalin, it cannot be supposed that the color has been destroyed in the one case and not in the other. To be sure, it is possible that the color increases with age, but this is not usual with ascidians.

The internal structural differences that do not seem explicable on the supposition that they are due to differences in age alone are the following: The tentacles are more numerous in *C. deani* than in *C. superba*, they being about twenty-four in the former and eighteen in the latter. In species in which these structures are small and very numerous, such a difference in number as this could not be considered as of great consequence; but where the number is small and the tentacles themselves are large, the difference certainly is of considerable importance, particularly since the larger number is found in the supposably younger specimens.

The much more highly coiled condition of the hypophyseal mouth in *C. superba* can, I think, hardly be considered as due to differences in age, although it must be admitted that the differences here are in the direction that would be expected on this supposition. But, judging from what we know of other ascidians, we are not warranted, I think, in believing that difference so great in this respect as that here found is to be thus accounted for.

Again, the differences in the branchial sacs and the accessory dorsal languets in the two forms are too great, I believe, to be explained away on this hypothesis. Compare figures 18 and 22, also 17 and 23.

The question of whether the *Cynthia coriacea* of Stimpson '64 is the species now under consideration must, I am convinced, with the data now at hand, be answered in the negative. Stimpson describes his species as being "smooth, and scarcely at all wrinkled." This statement clearly means that it is not only without wrinkles, but also that it is without asperities. It is true that the papillæ of our species are very small, but I can hardly believe they could have escaped so good an observer entirely. The branchial sac, the author says, "has about the same number of folds as the preceding species," referring to *Styela gibbsii*, which, he says, has 10 folds. As our species has

18, it hardly seems possible that Stimpson could have erred so widely as this. His statement that the "filaments at the summit of the branchial sac of *C. coriacea* appear to be few, and shaped like the palpi of the bi-valve acephala" I am at a loss to know how to interpret, but it certainly seems that if he had been examining our species the large branchial tentacles could not have escaped his notice, and certainly had he seen them he could not have compared them to the palpi of bivalve molluscs. On the whole I am inclined to think that his *C. coriacea* is in reality a *Styela.*

The nearest allies of these two closely related species are *C. papillosa* L., and *C. nordenskioldii* Wagn. But *C. papillosa* is very clearly distinguished from both, first of all, perhaps, by the distinct circle of long bristles borne by the margin of each orifice. Its papillæ are also larger throughout and are not arranged in the groups of primary and secondary ones as in our species.

From both *C. superba* and *C. deani*, *C. nordenskioldii* is distinguished superficially by its four-lobed atrial orifice; while in its internal structure it differs in possessing four gonads on each side, our species possessing only one.

All four of these species resemble one another in the possession of accessory dorsal languets. In *C. nordenskioldii*, to judge from the figure accompanying Wagner's description ('85), the transverse vessels on each side end in languets, so that the dorsal lamina is represented by a double row of them with a clear space between.

In *C. papillosa* there is a row of languets in the center of a broad clear space and besides these the transverse vessels on the right side end in languets, the arrangement being similar to that found in *C. deani.* This supplementary row of languets does not appear to have been anywhere described for *C. papillosa*, but an examination of specimens from Naples shows it to be present. The Pacific coast species seem to differ from the others in possessing the small accessory languets scattered between two rows and having no relation to the transverse vessels. This condition, as pointed out in the description of the species, is but feebly developed in *C. deani*, but much more highly so in *C. superba.*

Cynthia macrosiphonus n. sp.

(Pl. XX., Fig. 4 and Pl. XIX., Fig. 24.)

General Appearance: Whole animal, including siphons, 10.4 cm. long: exclusive of siphons 4.5 cm.: greatest diameter 2.7 cm. Siphons very long, the branchial nearly one and a half times as long as, and the atrial a little longer than the body. Both siphons four-lobed. Body attached on the left side near the posterior end by a broad base. Color a muddy brown shading in places to a yellowish brown; siphons lighter colored.

Test: In the posterior part, thick, coriaceous, prolonged into short processes at the point of attachment, thinner toward the anterior part. Dark over the body and over the lower part of the siphons; lighter, translucent and very smooth over nearly the whole of the branchial and the anterior half of the atrial siphon. Test on the anterior part of the body crumpled and irregularly wrinkled, that over the lower part of the siphons with deep transverse folds. An inner layer of test present, separating readily from the outer test and from the mantle. This inner layer soft, transparent, containing fibres and test cells; inner surface of outer test smooth, soft and shining.

Mantle: Thin; musculature well developed; dorsal muscle large; circular muscle bands at the base of the siphons, and both longitudinal and circular muscles of the siphons very strong.

Branchial Sac: Six folds on each side, about fourteen bars on a fold, and seven or eight between them; meshes oblong, often irregular, with usually four small oval stigmata; most of the transverse vessels of one size, but occasionally a very wide one present; series of stigmata frequently crossed by a small secondary vessel.

Tentacles: About fifteen in number: five (?) long slender ones with fine branches and smaller intermediate ones of at least two sizes.

Peripharyngeal Band: Widely separated from the tentacles, enclosing a large triangular space on the dorsal side on which the dorsal tubercle lies; mouth of the hypophysis with both horns turned in and once coiled (Pl. XIX., Fig. 24).

DORSAL LAMINA : Represented by very slender languets closely placed on a rather broad basal membrane (Fig. 24).

INTESTINE : Forming a wide loop.

GONADS : Two large branched organs, lying one on each side of the body.

There is only one specimen of this species in the collection and for this reason it has not been thoroughly dissected. Its external appearance, however, is very striking and should make it easily recognizable. The siphons are very long and flexible, and the smooth translucent test which covers them differs strikingly from the dark, crumpled and coriaceous test of the rest of the body.

The nearest allies of this species appear to be *C. squamulosa*, Alder, North-western Europe, and *C. dura* Heller, Atlantic, Mediterranean, and Pacific (Herdman), but the remarkable character of the siphons distinguishes it definitely from either of them.

Cynthia erecta n. sp.

(Pl. XVIII., Fig. 5.)

GENERAL APPEARANCE : Body barrel-shaped, of nearly the same diameter throughout ; length, exclusive of siphons, 3.6 cm., greatest diameter, 2.9 cm.; siphons placed at the dorsal and ventral edges of the body, 8 mm. apart ; branchial 1.4 cm. long, bent somewhat toward the ventral side ; atrial 9 cm. long pointing anteriorly ; color, in specimen preserved in formalin, light-gray, tinged with yellow at the posterior end ; siphons dark-brown.

TEST : Smooth in the anterior part, divided into irregular areas by slight folds toward the posterior end, especially on the left side ; prolonged into short processes at the posterior end where the body is attached ; also a few on the right side ; test not thick, but tough ; that of the siphons with deep transverse wrinkles as though much contracted.

INTERNAL STRUCTURE, as far as known, agreeing perfectly with that of *Cynthia macrosiphonus*, from which, however, it is very distinct in external characters.

The close correspondence in internal structure between this species and *C. macrosiphonus* naturally suggests the possibility that the two may in reality be but strongly marked variations of the same species, but the external differences are so great, not only in form and proportions, but also in texture of the test, that it hardly seems possible that they are not distinct species, and it is probable that further study of ample material will discover distinctive characters other than those now apparent.

C. erecta is undoubtedly a very close ally to *C. dura* Heller. From the accounts of the internal structure to *C. dura* as given by Heller, '77, and Traustedt, '83, I am unable to find any distinctions that would warrant the recognition of a separate species for my specimen. The external characters appear, however, to be very different. *C. dura* is a strongly depressed species, it never being even in young individuals where the form is, according to Heller "mehr rundlich," as high as broad. Again, according to both Heller and Traustedt, the test of *C. dura* is very hard and much tuberculated over the entire surface.

Cynthia castaneiformis von Drasche.

(Pl. XVIII., Figs. 6 and 7, and Pl. XIX., Fig. 25.)

Cynthia castaneiformis Drasche, '84, p. 373.
Cynthia castaneiformis Traustedt, '84, p. 27.

I identify this as von Drasche's species with some hesitation. von Drasche, however, made his description from a single specmen, and that a rather small one, hence probably an immature one. I therefore conclude that the discrepancies between his description and my observations are due to the insufficiency of specimens at his command.

The peduncle is described and figured as being as long as the body. In some individuals this is true; in others, however, the peduncle is longer than the body, and in still others it is shorter. The orifices are said to be "sitzend." In most preserved specimens they are so, but in life they are not (Figs. 6 and 7); they are quite prominent and are turned toward each other. In describing the processes of the test, the author makes no mention of secondary processes on the primary ones. In young individuals the processes are simple; in older ones, however, there are a few short secondary processes on the primary ones.

The author describes the branchial sac as having seven folds on each side; as a matter of fact there are eight, but in a young specimen it would be very easy indeed to fail to recognize all of them. The detailed structure of the branchial sac I have thought best to give complete, partly because of the inadequacy of von Drasche's description, and partly because of its very peculiar structure (Pl. XIX., Fig. 25). There are, as already said, eight folds on each side. These are large and closely placed. Each has about twenty internal longitudinal bars, and the interspaces between them two or three bars. The stigmata are elongated transversely to the direction of the endostyle and the folds of the sac. They are somewhat irregular in shape, size and arrangement, but on the whole they are arranged in series and in such fashion that a space is left between two adjacent series, against which the ends of the stigmata of each series abut. These spaces—longitudinal vessels they might be called—usually alternate with the internal longitudinal bars (Fig. 25, l. v.[1] and l. v.[2]).

The internal transverse vessels, or bars, are small and numerous, the typical arrangement being one between each two stigmata, Fig. 25 t. v.[2] These small transverse vessels connect with the internal longitudinal bars. Some of them cross the interserial spaces, or longitudinal vessels, and some do not, but terminate in these spaces. In addition to the small internal transverse vessels there are also larger ones, Fig. 25, t. v.[1], there being about ten of the smaller to one of the larger. The result of this arrangement is that typically each mesh of the branchial sac contains a single stigma.

von Drasche desribes and figures the stigmata to be nearly round. So far as there is any elongation, however, this is in the transverse direction, as shown by his Pl. XX. Fig. 9, I have for some years believed the *C. castanciformis* of von Drasche to be identical with *C. villosa* Stimpson, '64. Very recently, however, Herdman, '98, has re-described what he believes to be *C.*

villosa, and if he is right the two would seem to be quite distinct, although closely allied. They appear to differ both in external and in internal characters. As Herdman collected his specimens himself, he would have undoubtedly noted the pink color of the rather prominent siphons, had they been present, which distinguishes *C. castaneiformis* (Figs. 6 and 7).

Again, the spines of *C. villosa* appear to be both longer over the anterior portion of the body and to extend back over the pedunculated portion considerably more than is the case in *C. castaneiformis*.

As to internal structure although the two forms agree in the number of folds and the peculiarity as to direction of the stigmata, they differ markedly in the absence from the sac of *C. villosa* of the internal transverse vessels and the regular interserial spaces or vessels. (Compare Herdman's description and Pl. XII., Fig. 11.) Again it appears that the dorsal languets of *C. castaneiformis* are considerably more numerous and filiform than in *C. villosa*.

There are numerous specimens in the collection, and in addition it has been collected at several other points on our Coast south of Puget Sound.

Cynthia haustor Stimpson.

(Pl. XVIII., Figs. 8, 9 and 10.)

Cynthia haustor Stimpson, '64, p. 159.

Cynthia haustor von Drasche, '84, p. 372, Pl. III., Figs. 3 and 8.

Cynthia haustor Traustedt, '84, p. 29.

Cynthia haustor Herdman, '98, p. 257, Pl. XIV., Figs. 1 and 2.

But a single specimen of the species is contained in the collection; but as this is one of the most common representatives of the genus on our shore, north of San Francisco Bay, there can be no doubt as to its identification.

I am glad to be able to present the excellent figures drawn from the living animal by Doctor Dean.

Styela stimpsoni n. sp.

(Pl. XVIII., Fig. 11 and 12; and Pl. XIX., Fig. 26; and Pl. XX., Figs. 27 and 28).

General Appearance: Body irregularly oval; narrow at the anterior end where the siphons are placed; the atrial at the dorsal edge, and the branchial close to it, except in one specimen where it is 1.1 cm. distant. Body sloping gradually from the branchial siphon to the broad posterior end, where it is attached by root-like processes of the test. Average length of four specimens 3.2 cm., average of greatest diameter 3.1 cm. Siphons prominent though often contracted; both orifices four-cleft.

Test: Over the greater part of the body, thin, leathery, usually smooth, or with wrinkles due to contraction. Color, in life, as shown by Dr. Dean's figures, bright orange-red; this, however, wholly destroyed in preserved specimens, the color here being a light gray. Toward the posterior part the test becomes thicker, firmer, crumpled, and furnished with numerous processes and irregularities; color of this part usually a dark brown, tinged with yellow; inner surface of the test, smooth, white, and shining.

Mantle: Thick, composed of small but strong muscle fibers very densely woven in the upper part, somewhat more loosely woven in the lower part. Mantle closely attached to the branchial sac by many strong vessels.

Branchial Sac: Four folds on each side; the two folds on each side of the endostyle with four to six bars; the other folds stronger with ten to fourteen bars; four or five longitudinal vessels between the endostyle and the folds on each side; about six vessels between the other folds; transverse vessels of three sizes, usually five or six medium-sized ones between two broad ones; the series of stigmata often crossed by small secondary vessels which are sometimes incomplete. Meshes oblong with five to seven long, rather narrow stigmata in them (Pl. XIX., Fig. 26).

Tentacles: Unbranched, very numerous, of three lengths, about twenty long slender ones, with shorter ones alternating with them, and very short ones alternating with these, so that there are three short tentacles between two long ones; peripharyngeal band close to the circle of tentacles.

Dorsal Lamina: A broad membrane with its free margin irregularly cut and toothed; passing part way round the opening of the œsophagus which is placed nearly at the lower extremity of the branchial sac (Pl. XX., Fig. 27).

Dorsal Tubercle: Raised above the level of the branchial sac. Mouth of the hypophysis crescent-shaped with the horns coiled in, forming small spirals; opening toward the left side.

Digestive Tract: Forming a narrow loop; stomach long and narrow, marked with numerous longitudinal lines which are formed by the folds within the stomach.

Heart: Very conspicuous, a long slender tube lying close against the lower side of the stomach, but closely attached to the mantle by large vessels.

Gonads: Numerous, eight to ten on each side of the body, in the form of long, slender tubes, sometimes bent on themselves and somewhat twisted: each tube ending in a large but short vas deferens. Endocarps numerous (Pl. XX., Fig. 28.)

There are six specimens of this species in the collection. Of the six, three have their long axis directed anterio-posteriorly, while the other three have it in the opposite direction. These latter three, however, show signs of being much contracted.

This species agrees in many particulars with *S. joanæ* Herdman '98, but differs from it in external form and color, *S. joanæ* being "whitish gray." (Since Herdman himself collected the single specimen upon which his description is based reference is of course here made to the color in life.) The musculature of *S. joanæ* is said to be "very delicate," and the mantle thin. The dorsal lamina is a "plain narrow membrane," and the tentacles are "long and slender, closely placed, about forty in number," apparently not differing greatly in length, as is the case in *S. stimpsoni.* It is also closely related to *Polycarpa finmarkiensis*, Kiaer '93, but from this it differs in having a much larger number of tentacles, twenty to twenty-five being the number in this latter species; in the uncoiled condition of the horns of the hypophysis mouth of *P. finmarkiensis*, and in the absence of toothing (presumably so, since no mention is made of the teeth by the author) on the edge of the dorsal lamina of the European species.

Styela gibbsii Stimpson.

(Pl. XVIII., Figs. 13 and 14.)

Cynthia gibbsii Stimpson, '64, p. 159.

Styela gibbsii Herdman, '98, p. 261, Pl. XIII., Figs. 1–4.

There are ten specimens of this well-defined species in the collection. Herdman's recent redescription supplements Stimpson's original rather meager description so well that it is unnecessary for me to add anything from the data at hand beyond the presentation of Dr. Dean's figures from life.

Ascidia koreana Traustedt.

Phallusia koreana Traustedt, '84, p. 14, text Figs. III. and IV., Pl. II., Fig. 15.

I have considerable doubt about the correctness of this identification. It is very possible that careful study of sufficient material of both the Puget Sound and the Corean forms will prove them to be specifically distinct, but pending the opportunity for such study, I have not thought it justifiable to separate them on the evidence at hand. The Puget Sound forms appear to have a larger number of tentacles than have the Corean forms.

There are five specimens in the collection.

Corella willmeriana Herdman.

(Pl. XVIII., Fig. 15.)

Corella willmeriana Herdman, '98, p. 252, Pl. XI., Figs. 1–4.

The collection contains a single specimen of what I identify as this species.

The only point of difference I note between the individual at hand and Herdman's description, is in the character of the surface of the test. The author speaks of this as being "very smooth and glistening," whereas in my specimen it has many inconspicuous asperities.

Chelyosoma producta Stimpson.

Chelyosoma producta Stimpson, '64, p. 161.

Chelyosoma productum von Drasche, '84, p. 381, Pl. VII. Figs. 5–9.

Chelyosoma productum Traustedt, '84, p. 7.

Chelyosoma productum Herdman, '98, p. 252.

Chelyosoma productum Bancroft, '98.

A large number of this very common Puget Sound species is contained in the collection.

Distoma molle n. sp.

(Pl. XX., Figs. 29 and 30.)

General Character of the Colony: Comparatively regularly disc-shaped, attached by nearly the whole of the under surface. Greatest diameter of the larger of the two colonies at hand 8.6 cm.; shorter diameter of same colony 5.5 cm.: thickness in thickest portion 2 cm. Very soft and flabby. Test more than usually transparent, the individual zooids showing through it very distinctly. Color, a light gray, this being imparted to the otherwise quite transparent testicular mass by the thin, somewhat more opaque superficial layer to which a small quantity of fine sand adheres. The soft testicular substance contains many cells which are small and rather uniform in form and size; no bladder cells present.

General Character of Zooids: Distinctly seen through the test for nearly their entire length. No systems recognizable. Placed mostly at oblique but varying angles to surface of colony. Each zooid in the form of a dumbbell with a very long handle, the thorax forming one of the balls, the intestinal loop the other, and the much elongated œsophagus and rectal portion of the intestine the handle, the two ends or balls being nearly equal in size. Average length about 8 mm., of which about 5 mm. belong to the handle of the dumbbell. The ectodermal appendage at the posterior end of the abdomen large and always present.

Branchial Apparatus: No orifices, either branchial or atrial, recognizable on the surface of the colony; this probably due to the extreme flabbiness of the test. Branchial and atrial siphons about equal in size and shape, both long and strong; the lobes of each well marked—almost tumid in some specimens. Thorax always much contracted, very dense, so that its internal structure is made out with great difficulty. Apparently three series of long stigmata in the branchial sac; but the extreme state of contraction makes certainty on this point impossible. Musculature of mantle well developed, particularly as to the circular fibers, these arranged in more or less regular bands, as are the longitudinal ones; the circular fibers almost as well developed at the posterior as at the anterior end of the thorax.

DIGESTIVE APPARATUS: Œsophagus very long and narrow; stomach nearly globular, its walls somewhat irregularly thickened, but not distinctly folded. Post gastric intestine short, the intestinal loop forming almost a circle, the stomach being situated at the point where the intestine returns upon itself to produce the circle. Rectal portion of the intestine very long, running closely parallel with the œsophagus.

SEXUAL ORGANS: Situated on the left side of the intestinal loop, but extending slightly behind it; ovary not voluminous though the individual ova when fully grown are large; the ovary on the œsophageal side of the intestinal loop, and immediately behind the stomach. Testis forming a dozen or more large, distinct elliptical masses; vas deferens distinct throughout its length when filled with sperm.

Embryos developed in the atrial chamber, this not produced into a special incubatory pouch; apparently about six embryos and tadpoles in the chamber at one time.

Distoma lobata n. sp.

(Pl. XX., Figs. 31, 32 and 33.)

GENERAL CHARACTERS OF COLONY: Massive, the smaller ones rather regular, thick cake-like, the larger ones very irregular and prominently lobulated. Largest specimen 10 cm. long, 4 cm. wide in widest part; most prominent lobe 3.5 cm. high and 3 cm. in diameter. Texture firm, but not hard. No sand imbedded in test, and entire surface very clean. Color, transparent white. Outlines of the zooids and the branchial orifices distinctly seen on the surface.

ZOOIDS: Numerous closely set, evenly distributed, very much contracted in all the specimens at hand; disposed rather regularly perpendicularly to the surface of the colony; systems present, though not conspicuous; zooids in each not numerous. Average length, as determined by measuring the depth to which they reach in the test, about 6.5 mm., actual average length in the contracted state assumed by nearly all the individuals about 2.5 or 3 mm.; a few found with length as great as 4.5 mm.

The long-pedunculate portion of the body between the thorax and the gastro-genital mass which characterizes the zooids in the normal condition, is wholly obliterated in the contracted state (Fig. 32).

TEST AND MANTLE: Former without sand grains; quite uniform in texture, made up largely of bladder-cells, the small cells being comparatively few; no vessels present. Mantle well developed, both longitudinal and circular muscle fibers being numerous and strong.

The ectodermal appendages given off from posterior portion of mantle seem to be less prominent here than in most species of the genus, though they are present.

BRANCHIAL APPARATUS: Branchial orifice easily distinguishable on surface of colony, the common atrial orifices rather obscure. Both siphons prominent on detached zooid, the atrial particularly long, though variable for different individuals; both with six well marked, broad, short lobes. Internal structure of the thorax determined with much difficulty on account of the heavy musculature of the mantle and the extreme state of contraction. Branchial tentacles apparently about twenty-four in number, of moderate length. Endostyle heavy, closely tortuous. Apparently five series of stigmata, though some uncertainty here.

Dorsal languets not seen.

DIGESTIVE TRACT: Œsophagus very long. Stomach and intestinal loop proper forming a prominent mass at the extreme posterior end of the zooid, stomach apparently somewhat longer than broad, wall nearly or quite smooth, but extreme state of contraction makes certainty here impossible. Intestinal loop rather narrow, rectal portion running close along and parallel with œsophagus; rectum in all specimens examined contained several large, elliptical, dark colored fœcal masses; anus about midway of the length of the branchial sac.

REPRODUCTIVE ORGANS: Both ovary and testis placed alongside the intestinal loop, the latter extending somewhat, though but slightly behind it; ovary small and with few ova in all the specimens at hand; testis rather large, in the form of a quite regular rosette. No embryos or buds seen.

This species is closely related to a *Distoma* that is widely distributed on the coast of California, and which I have designated in my MS. notes as *Distoma y*. It appears, however, to be specifically distinct from it, *D. y*, being almost always without systems, while *D. lobata* almost always possesses them. The "bladder" cells, which are so characteristic of the test of *D. lobata*, appear to be wholly wanting in *D. y*. Again, I have never seen colonies of *D. y* of anything like the size of the largest specimen of *D. lobata*.

Interestingly enough the species resembles quite closely *D. illotum* Sluiter from the coast of South Africa, though it is undoubtedly specifically distinct from it.

Amaroucium californicum Ritter (MS.).

The *Amaroucium* which I identify as *A. californicum* is well known to me from its abundance at various places on the coast of California, particularly at Monterey Bay. The only point in which the northern specimens present any difference from the more southern ones is in the length of atrial languet. On the whole this structure seems to be somewhat longer in the former than in the latter. But its great variability, not only in general, but particularly in zooids of the same colony, precludes the possibility of attaching any great importance to the difference noted.

Distaplia occidentalis Ritter (MS.).

Distaplia occidentalis Bancroft, '99, p. 59.

Next to *Amaroucium* no other genus of compound ascidians is more abundantly represented, at least as to number of individuals, on our coast than is *Distaplia*. They present great variety in form and size of colony, and in color, and I have, at various times and from various localities, entered provisionally in my notes at least four species. These have, however, always been differentiated on superficial characters, *i. e.*, characters of the colonies. The attempt to find constant structural differences between the zooids of the supposed species have been unsuccessful thus far, and as the superficial characters are found, upon examination of a very great quantity of material collected at different seasons of the year, to be exceedingly variable and inconstant, I am now of the opinion that but a single species has yet come under my observation. The differences in color and form and size of colony are probably due to differences in age, state of development of the zooids, and perhaps of other factors not yet recognized.

The colonies contained in the present collection are somewhat larger and thicker than is usual with specimens from points farther south, but beyond this I find nothing distinctive in them.

UNIVERSITY OF CALIFORNIA, BERKELEY, CALIFORNIA, July 14, 1898.

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PLATE XVIII.

PLATE XVIII.

PUGET SOUND ASCIDIANS.

	PAGE.
Fig. 1. **Cynthia superba** Ritter, × 1	590
Figs. 2 and 3. **Cynthia deani** Ritter, × 1	592
Fig. 5. **Cynthia erecta** Ritter, × 1	598
Figs. 6 and 7. **Cynthia castaneiformis** von Drasche, from life, × 1	599
Figs. 8, 9 and 10. **Cynthia haustor** Stimpson, from life, × 1.	601
Figs. 11 and 12. **Styela stimpsoni** Ritter, from life, × 1	602
Figs. 13 and 14. **Styela gibbsii** Stimpson, from life, × 1	604
Fig. 15. **Corella willmeriana** Herdman, from life, × 1	604

PLATE XIX.

PLATE XIX.

PUGET SOUND ASCIDIANS.

PAGE.

Fig. 16. **Cynthia superba** Ritter, showing papillæ, × 60. 590

Fig. 17. Dorsal tubercle and portion of dorsal languets of same species, × 4. 591

Fig. 18. Branchial sac of same. 591

Fig. 20. A single tentacle of same. 591

Fig. 21. **Cynthia deani** Ritter, × 60. Portion of test with papillæ 592

Fig. 22. Branchial sac of same species. 592

Fig. 23. Tentacles, dorsal tubercle, and dorsal languets of same species, × 10. 593

Fig. 24. **Cynthia macrosiphonus** Ritter, × 4. Tentacles, dorsal tubercle, and dorsal lamina. 597

Fig. 25. **Cynthia castaneiformis** von Drasche, branchial sac 599

Fig. 26. **Styela stimpsoni** Ritter, branchial sac. 602

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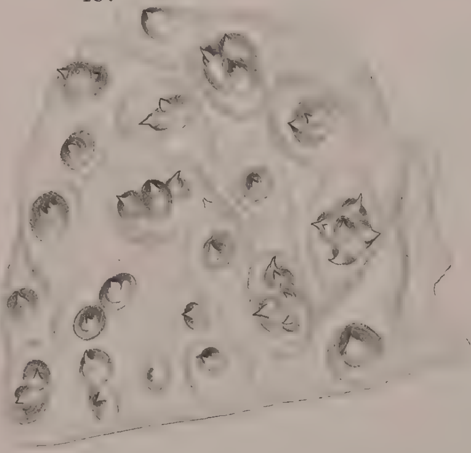

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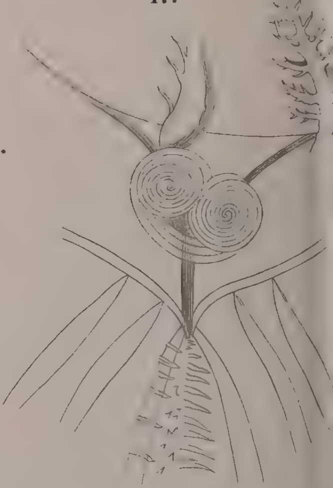

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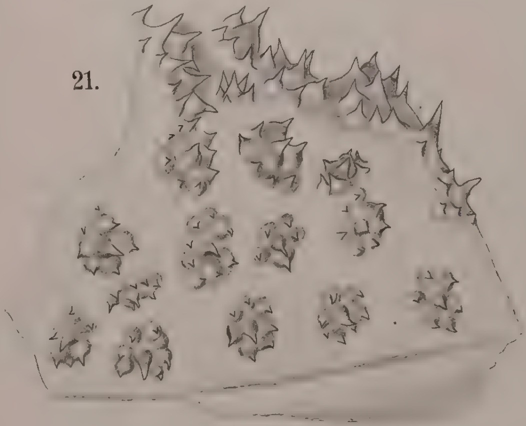

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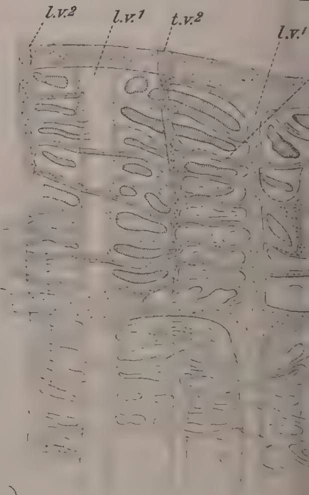

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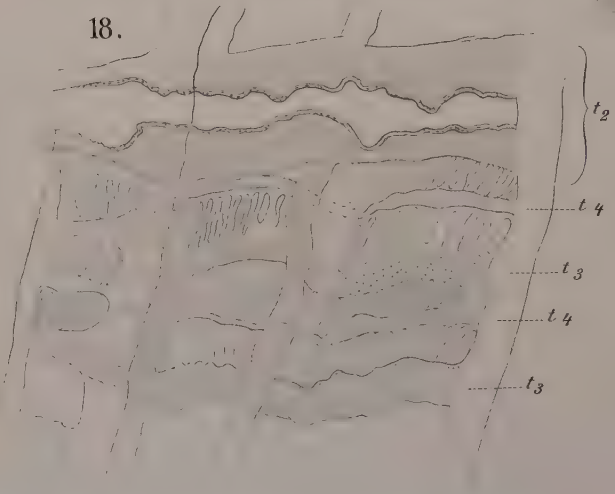

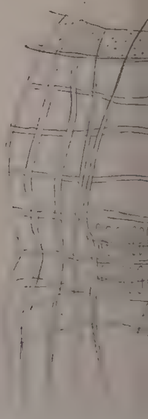

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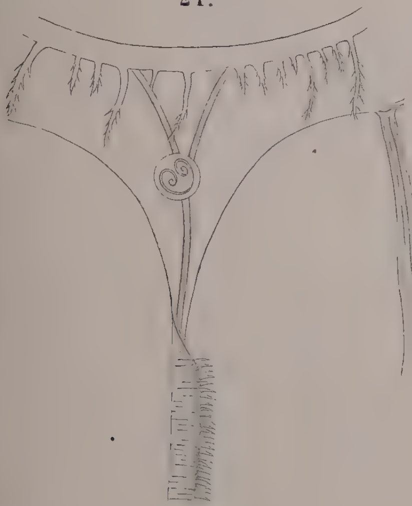

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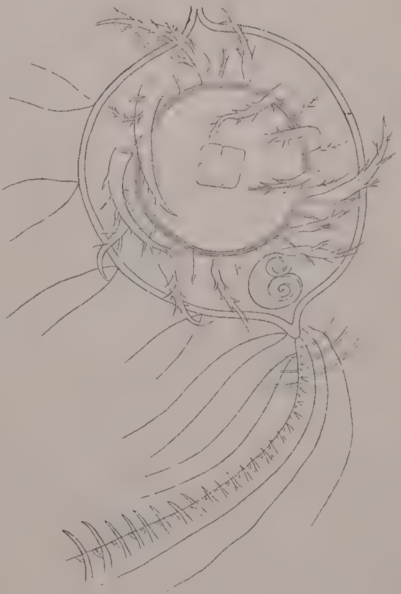

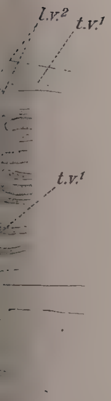

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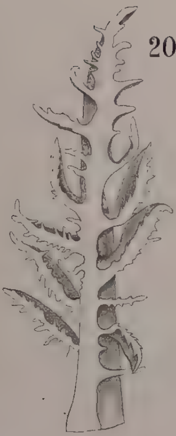

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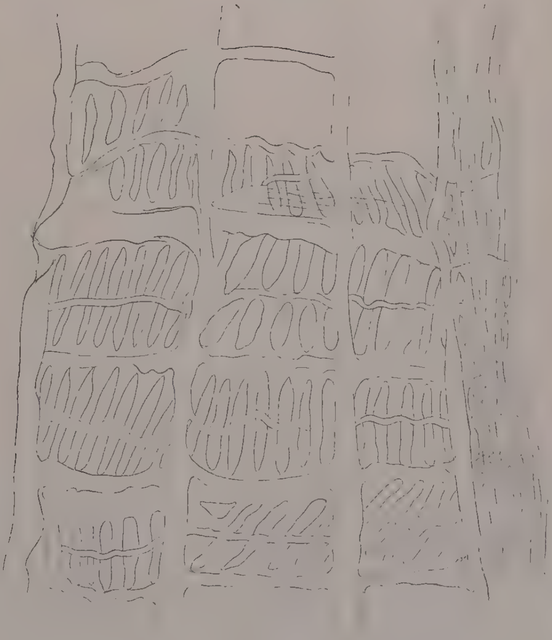

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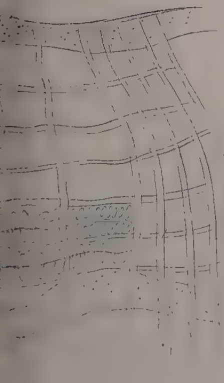

Lith. Anst. v. E. A. Funke, Leipzig.

PLATE XX.

PLATE XX.

PUGET SOUND ASCIDIANS.

	PAGE.
Fig. 4. **Cynthia macrosiphonus** Ritter, × 1	597
Fig. 19. **Cynthia superba** Ritter. Dorsal languets, primary and secondary	590
Fig. 27. **Styela stimpsoni** Ritter, Dorsal lamina	602
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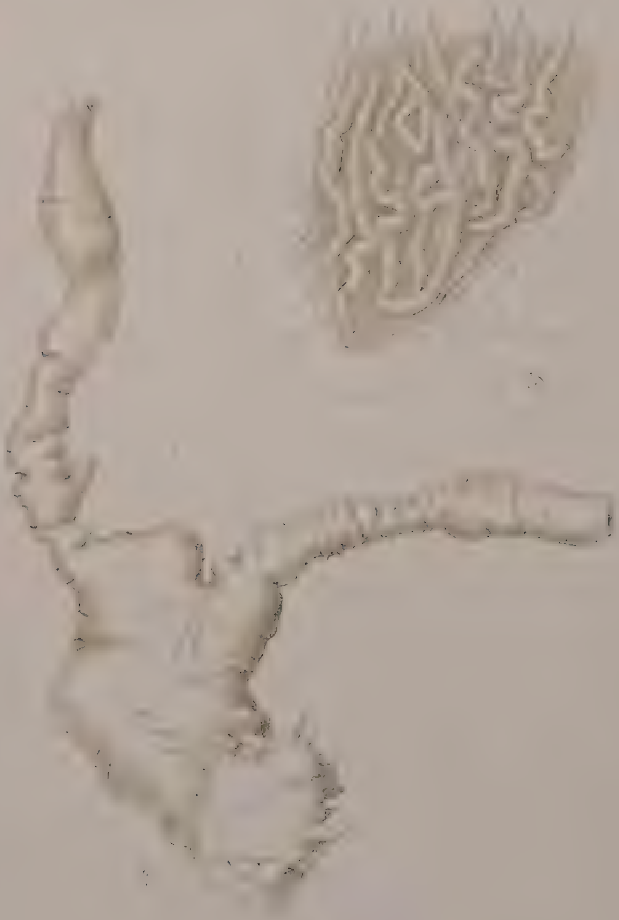
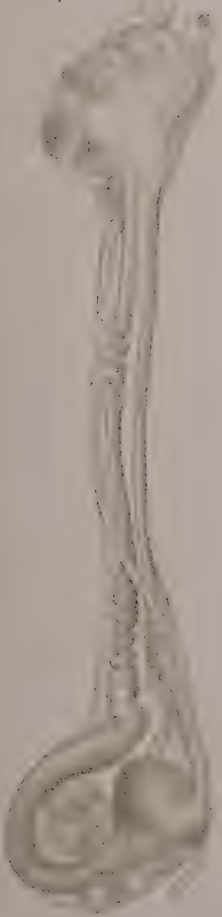
Figs. 29 and 30. **Distoma molle** Ritter, the first in contracted state, the second in extended, × 12	605
Fig. 31. **Distoma lobata** Ritter, general character of colony × 1	606
Figs. 32 and 33. Same species, first in contracted state, second extended, × 27	606





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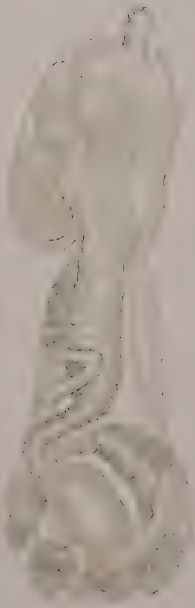

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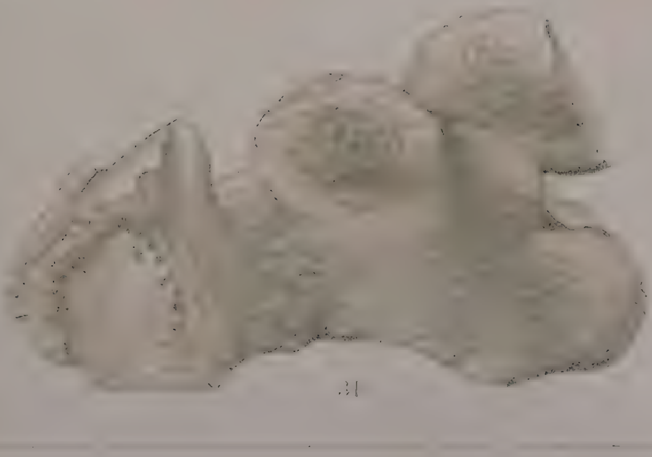

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[ANNALS N. Y. ACAD. SCI., XII., No. 15, pp. 617 to 690, June 2, 1900.]

RECORDS OF MEETINGS

OF THE

NEW YORK
ACADEMY OF SCIENCES

JANUARY, 1899, TO DECEMBER, 1899

RICHARD E. DODGE
Recording Secretary

[Annals N. Y. Acad. Sci., XII., No. 15, pp. 617 to 690, June 2, 1900.]

RECORDS OF MEETINGS

OF THE

NEW YORK ACADEMY OF SCIENCES.

January, 1899, to December, 1899.

Richard E. Dodge, *Recording Secretary.*

BUSINESS MEETING.

January 2, 1899.

Academy met at 8 P. M., Vice-President Kemp presiding. The minutes of the last business meeting were read and approved.

The following candidate for resident membership, approved by the Council, was duly elected:

Samuel Thorne, 43 Cedar St., New York, N. Y.

There being no further business, the Academy adjourned.

Richard E. Dodge,
Recording Secretary.

SECTION OF ASTRONOMY AND PHYSICS.

January 2, 1899.

Section met at 8 P. M., Mr. P. H. Dudley presiding. The minutes of the last meeting of Section were read and approved. The following program was then offered:

Wm. Hallock, A Model to Illustrate Kirchhoff's Principle.

F. L. Tufts, On the Absorption and Reflection of Sound Waves by Porous Materials.

P. H. Dudley, TRANSLATIVE CURVES OF COUNTER BALANCE AND CRANK PINS IN RUNNING LOCOMOTIVE.

In the absence of the Secretary, Mr. Theodore G. White was elected Secretary *pro tem.*

The principle illustrated in Professor **Hallock's** paper may be stated as follows: Any system that has an inherent rate of vibration in itself, will respond to vibrations of the same period as its inherent vibration factor, but is indifferent to vibrations faster or slower than that particular rate of inherent vibration. The model consists of a brass ring, on the center of which a brass ball is held in equilibrium by means of three spiral springs which are attached to points equi-distant from one another around the circumference of the ball, and at their other extremities to points equi-distant from one another, upon the inner circumference of the ring. The model is suspended from the axis perpendicular to the plane of the ring and springs. Vibrations are imparted to the model thus suspended, by means of a string, or better, by means of a spiral of wire, attached to the ring, and held by the hand in a horizontal position. Vibrations delivered through the weak spiral spring, impart a succession of impulses to the ring, while the ball has its own inherent rate of vibration in the plane of the ring itself, due to its mode of suspension. When the vibrations imparted to the ring are too rapid or too slow, beats are produced, which disappear as the rapidity of the induced vibrations approaches the inherent rate of vibration. A modified form of the same apparatus consists in suspending the former apparatus concentrically within a second brass ring, so as to connect the two rings. One rate of impulses is then imparted to the outer ring, and by means of the spirals connecting the concentric rings, another set of impulses is imparted to the second ring, according to their inherent rates of vibration.

In the discussion of this paper, Professor **D. W. Hering** suggested connecting the string or spiral by which impulses are imparted to the ring, to a tuning fork, the rate of vibration of which could be regulated by weighting and which could be operated electrically for reciprocating motion of small amplitude and of a known rate.

The second paper, by Dr. **Tufts**, gave the results of experiments on the transmission and reflection of sound by such materials as flour, sand, sawdust, shot, and a few different kinds of cloths. It was stated that when sound waves strike against materials pervious to air they act very much like a pneumatic pressure, and that the amount of sound transmitted through such materials is inversely proportional to the resistance offered by the materials to the passage of a direct current of air. The results of the experiments upon the reflection of sound from the same materials showed that those materials which transmitted the greatest amount of sound reflected the least. The paper also contained an account of some experiments in which the sound waves had to pass through some pervious material, such as the curtain upon a wall, and were then reflected back through the same by the impervious wall. The results of these experiments showed that there was greater reflection when the curtains were of very porous or of very impervious materials, than when they were of materials of medium porosity, such as velvet.

In the discussion that followed, Professor **Hallock** suggested the practical application to the improvement of the acoustics of rooms which might result from these investigations, and the uselessness of the method of stringing wires in large halls to break up echoes which had been often advised but which was disproved by these investigations. Mr. **Dudley** also spoke of the attempts which had been made to obtain materials absorptive of sound to deaden the noise in railroad cars.

The third paper by Mr. **Dudley** was profusely illustrated by lantern slides. These showed the loci of the center of gravity of the counter-weights, crank pins and driving axles in running locomotives. Some of the photographs showed the position of the counter-weights in the driving wheels of running locomotives in reference to the stremmatograph under the rail. The counter-weights added to locomotive driving wheels to balance the reciprocating parts, crank pins, main and side connecting rods, when the locomotive is running, besides rotating around the axles, move along the rails per revolution, a distance equal to the circumference of the drivers. The locus of the center of gravity of the counter weights six inches from the tread of the tire in a seven foot driving wheel, travels above the locus of the driving axle, over three times as far as it does below.

The locus of the center of gravity of the crank pin for 24-inch stroke of piston in a driving wheel of 7 feet diameter, travels 44 per cent. more above the locus of the driving axle than below.

The above cited facts show that the relative velocities of the center of gravity of the counter weights and crank pins are not constant, for each portion of a revolution as in the stationary engine, but are unequal and constantly changing. Therefore the forces generated are unequal, and perfect counter-balance does not obtain in the locomotive. Part of the unbalanced forces must be absorbed by the locomotive, and part by the permanent way. The upper portion of the driving wheel moves much faster than the lower portion running on, and in contact with, the rail, in striking contrast to the uniform velocity of the rim of the fly wheel of a stationary engine.

Mr. **Dudley** also showed lantern slides of running locomotives, in which the lower spokes of the driving wheels were sharply defined, while the upper ones, running so much faster, were not stopped for the same exposure.

The Section adjourned at 9.40 P. M.

THEODORE G. WHITE,
Secretary pro tem.

SECTION OF BIOLOGY.

JANUARY 9, 1899.

Section met at 8 P. M., Professor Lee presiding. The minutes of last meeting of Section were read and approved. The following program was then offered:

Robert W. Shearman, THE SKULL OF A CHIMÆROID.

Richard Weil, AN ANOMALY IN THE INTERNAL COURSE OF TROCHLEA NERVE.

J. L. Wortman, HISTORY OF THE DEVELOPMENT OF THE CANNON-BONE IN ARTIODACTYLA.

George S. Huntington, THE MORPHOLOGY AND PHYLOGENY OF THE VERTEBRATE ILIOCOLIC JUNCTION.

Mr. **Shearman** described the chief branchial and cranial features of the Chimæroid (*Hydrolagus collei*) and brought out facts to show that the group Holocephali should be regarded as a suborder of the Elasmobranchii instead of an order as is customary at present. The paper was discussed by Professors **Osborn** and **Huntington.**

Mr. **Weil** described very briefly an abnormal course of the trochlea nerve in a human embryo.

Dr. **Wortman** substituted the paper as given above for the one which he was announced to give, viz., "Notes on an Amphichelydian Tortoise from the Jurassic of Wyoming."

Dr. **Wortman** showed that the formation of the Cannon-bone of the camels, represented possibly in potential, in forms as early as *Protylopus* of the Eocene, and in various stages of development in *Pœbrotherium*, *Protolabis*, *Procamelis* and *Auchenia* down to the modern *Camelis*. The various stages in the process were described as follows: 1st. There was a reduction of the soft tissue between the metapodials and a flattening of the contiguous sides with a consequent loss of motion of the bones upon one another. 2nd. The articular surfaces were reduced and the sides of the bones became roughened for the stronger attachment of ligaments. 3rd. The bones became joined by the formation of bony tissue at the line of union, a suture marking the place of contact. 4th. The bones finally became firmly united in a large part of their extent, even the suture disappearing at an early period of development of the individual.

Dr. **Wortman** considered these facts as evidence that the Cannon-bone in its incipiency is the result of a senile change, i. e., acquired with the age of the animal, and that, as evolution progressed, its formation was brought about earlier and earlier, until in modern camels it is clearly an inter-uterine formation. This, he maintained, is clearly an instance of the inheritance of an acquired characteristic.

In discussing the paper, Professor **Osborn** remarked that undoubtedly these changes were acquired characters, but the induction could not be safely made from them that acquired characters are inherited. By the theory of "Organic Selection" advanced by Morgan, Baldwin and Osborn, such characteristics persist for very long periods without becoming hereditary. Even as senile characters, they are adaptive, and if they appeared in certain individuals at a slightly earlier age than others, those in which they appeared earlier would possess a slight advantage over others, and thus, after a very long period of time, probably thousands of years, a senile character would become a juvenile character and finally a congenital or fully hereditary character, as in the camels.

Professor **Huntington** exhibited a large number of slides to show the variations in the Iliocolic Junction of different types of vertebrates.

GARY N. CALKINS,
Secretary.

SECTION OF GEOLOGY AND MINERALOGY.

JANUARY 16, 1899.

Section met at 8 P. M., Professor Kemp presiding. The minutes of the last meeting of Section were read and approved. The following program was then offered:

F. J. H. Merrill, ON THE ORIGIN OF THE WHITE CLAYS OF LONG ISLAND.

George F. Kunz, ON THE FINDING OF NATIVE SILVER IN DAVIDSON CO., N. Y.

R. Ellsworth Call, THE GEOLOGY OF MAMMOTH CAVE.

Dr. **Merrill** described in his paper white clays as being strongly marked at many points along the western part of the north shore of Long Island in connection with the Quarternary deposits. In seeking for their source on the mainland he had reached the conclusion that they are probably identical with the white and vari-colored residual clays derived from the decomposition of the limestone beds of New York and Westchester Counties. If this be true, their absence farther east may be explained. Dr. Merrill illustrated his paper with numerous specimens of both the residual clays from the mainland and their transported equivalents from Long Island, together with maps and charts.

He also gave a brief account of some recent studies regarding the peculiar course of the Hudson River in its passage through the Highlands. He pointed out the fact that while the general stream courses of the region are determined by the line of strike, they are modified greatly by fault-lines having a somewhat N. W.–S. E. course, transverse to the strike. He next showed that the sharp turn taken by the Hudson in cutting through the Highland range diagonally, instead of conforming to its trend, strongly suggested that in the same way it has here followed a fault-line.

The paper was discussed with much interest by Professor **Dodge** and other members.

Mr. **Kunz** in his paper described the discovery of native silver at Silver Hill, N. Y., where the metal occurs in peculiar fibrous and minutely crystalline masses. Specimens weighing over ten ounces each of quite pure silver were exhibited.

Dr. **Call** read a very comprehensive paper dealing with the origin, history and present condition of the Mammoth Cave, and illustrating his remarks with an extended and beautiful series of lantern slides and maps.

GEORGE F. KUNZ,
Secretary.

SUB-SECTION OF ANTHROPOLOGY AND PSYCHOLOGY.

JANUARY 23, 1899.

Section met at 8 P. M., Professor Boas, presiding. The minutes of the last meeting of Section were read and approved. The following program was then offered:

Charles H. Judd, THE VISUAL PERCEPTION OF LINEAR DISTANCES.

B. B. Breese, A MODIFICATION OF PSYCHOPHYSICAL METHODS.
A. Hrdlicka, THE PAINTING OF BONES.

CHARLES B. BLISS,
Secretary.

PUBLIC LECTURE.

JANUARY 30, 1899.

A lecture was given under the auspices of the Section of Geology and Mineralogy by Rev. **Horace C. Hovey,** D.D., of Newburyport, Mass., on THE REGION OF THE CAUSSES IN FRANCE, THEIR CAVES, CANYONS AND PRE-HISTORIC REMAINS. The lecture was followed with the greatest interest by the fifty members present and at its conclusion a vote of thanks was extended to the speaker.

J. F. KEMP,
Secretary pro tem.

BUSINESS MEETING.

FEBRUARY 6, 1899.

Academy met at 8 P. M., Mr. P. H. Dudley, presiding.

The reading of the minutes of the last meeting was dispensed with.

The Secretary presented the list of nominations of honorary and corresponding members and fellows to be voted on at the next annual meeting, which list had been prepared by the Council in accordance with the by-laws.

The Secretary announced that Professor William Hallock was to conduct the Sixth Annual Reception and Exhibition.

There being no further business, the Academy adjourned.

RICHARD E. DODGE,
Recording Secretary.

SECTION OF ASTRONOMY AND PHYSICS.

FEBRUARY 6, 1899.

Section met at 8.30 P. M., Mr. P. H. Dudley, presiding.

The following program was then offered:

L. J. R. Holst, THE INFLUENCE OF THE NEW JENA GLASS ON MODERN OPTICS.

Mr. **Holst** gave in his paper a short account of the development of photography and photographic lenses, and in addition showed a number of photographs taken with some of the standard lenses in regular use, as well as several that were taken by a similar lens of Jena glass. The latter showed much better definition over a broader field. A number of micro-photographs were also exhibited, showing that with Jena glass a greater depth of focus is obtained than with ordinary optical glass.

A general discussion on the paper followed and a vote of thanks to Mr. Holst was tendered by the Section.

F. L. TUFTS,
Secretary pro tem.

SECTION OF BIOLOGY.

FEBRUARY 13, 1899.

The following program was offered:

Francis B. Sumner, OBSERVATIONS ON THE GERM LAYERS OF TELEOST FISHES.

Gary N. Calkins, THE EVOLUTION OF THE KARYOKINETIC FIGURE.

Frederic S. Lee, THE CAUSE AND SIGNIFICANCE OF MUSCLE FATIGUE.

Owing to the severe storm on the night preceding it was decided by the Chairman and the Secretary, that the meeting be postponed.

GARY N. CALKINS,
Secretary.

SECTION OF GEOLOGY AND MINERALOGY.

FEBRUARY 20, 1899.

Section met at 8 P. M., Professor Kemp presiding. The minutes of the last meeting of Section were read and approved.

The Chairman announced his great regret that the speaker for the evening, Professor R. D. Salisbury, who was to read a paper on "The Surface Geology of New York and Vicinity," was unavoidably detained in Chicago, and had telegraphed his regrets and apologies.

Dr. **Wallace G. Levison** gave a brief preliminary note on recent experiments made by him in regard to the emission of "uranium" or "Becquerel" rays by certain uranium minerals, especially uraninite. He wrote and drew figures on a card with glue and covered the designs with powdered uraninite which adhered to the marked portions. This card he then placed upon a photographic plate that was completely wrapped in black paper, and protected from contact with the uraninite and from exposure to light-rays; and in two or three days a sharp image was produced on the plate. Further experiments had enabled him to reduce the time. He was still engaged in these tests, and had not intended to speak of them at present, but did so on this occasion, as the regular paper had failed and the evening was open.

The Chairman, Professor **Kemp**, stated that in Professor Salisbury's absence, he had undertaken to occupy a part of the time and would give a paper "ON THE TITANIFEROUS MAGNETITES." He described the two great groups of magnetites long since recognized as with or without the presence of titanium, and the mode of occurrence of the two, the purer magnetites chiefly in granitic and gneissoid rocks, and the titaniferous ones closely associated with rocks distinctly igneous, and apparently separated out from them in the process of cooling. He then discussed the theories as to the manner in which the titanium was combined, and the formulas proposed to express the relations which are still matters of some uncertainty. The geographical occurrences were then dealt with, in Canada, the Adirondacks and Wyoming, and abroad in Sweden and Norway. A series of analyses was then presented on the screen, and the other relations of the various ingredients discussed, with special reference to replacements, etc.

The results of many analyses were shown in a remarkably interesting chart, in which the relations of the components were plotted in curves, and important deductions were made possible to the view.

Professor Dr. **H. Lundbohm,** of Sweden, was present and addressed the meeting by invitation. He expressed his great interest in the paper of the Chairman and gave some additional facts with regard to the titaniferous ores of Sweden.

Mr. **Kunz** raised the question, suggested by the chart, as to the replacement of phosphoric acid by vanadic in the apatites as in the lead compounds. The Chairman had distinctly noted the fact that the chart showed the two acids to be present in inverse relations but was not aware that the replacement had ever been recognized with lime, as with lead, and thought the vanadium more probably present in some other association, perhaps with the chromium.

Another point, raised by Dr. Lundbohm, was treated, namely, the especial superiority possessed by or claimed for some varieties of iron made from titaniferous ores. The Chairman held that this superiority for some purposes, such as car-wheels, might perhaps be due to the presence of certain other elements associated in most of these titaniferous ores such as small amounts of nickel, cobalt, etc., rather than to the titanium, which is not generally regarded as an advantageous ingredient.

There is trouble and cost in working these ores, which have thus far made the attempts in many cases unprofitable in competition with cheap and easily worked ores from Lake Superior and Alabama; but there is no insuperable difficulty, and the titaniferous ores constitute a great reserve supply for the future.

Professor **D. S. Martin** read a short BIOGRAPHICAL NOTICE OF THE LATE MR. CHARLES W. A. HERRMANN of this city, who died June 20, 1898, at the age of 97, and was long known in former years as a student, dealer and importer of minerals, and exerted an important influence in the third quarter of this century in making European minerals familiar and accessible to American students and collectors.

GEORGE F. KUNZ,
Secretary.

SUB-SECTION OF PSYCHOLOGY AND ANTHROPOLOGY.

FEBRUARY 24, 1899.

Section met at 8 P. M., Professor Bliss, presiding. The minutes of the last meeting of Section were read and approved.

The following program was then offered:

F. Boas, ON ANTHROPOMETRIC CHARTS.

F. C. Spencer, ORIGIN AND PERSISTENT INFLUENCE OF SACRED NUMBER CONCEPTS.

R. S. Woodworth, THE ACCURACY OF MOVEMENT.

CHARLES B. BLISS,
Secretary.

ANNUAL MEETING.

FEBRUARY 27, 1899.

Academy met for the annual meeting with President Osborn in the chair. The minutes of the last annual meeting were read and approved.

The Corresponding Secretary reported concerning his work during the previous year in correcting and arranging the list of honorary and corresponding members, which work called for an extensive amount of labor. The accompanying report of the Recording Secretary was then submitted, followed by the accompanying report of the Treasurer, which was referred to the Finance Committee for auditing.

The Editor of the ANNALS made a verbal report of the progress of the ANNALS during the year, and of the many plans for the improvement of the Academy publications which he had been able to put in operation.

The last official report was that of the Librarian, which is herewith filed and which was read by the Recording Secretary.

The following nominations for honorary members were read as selected by the Council:

Lord Rayleigh, M.A., D.C.L., LL.D., F.R.S., Royal Institution of Great Britain, Albemarle street, Piccadilly, N. W., London.

George Howard Darwin, M.A., F.R.S., Trinity College, Cambridge, England.

Professor J. K. Rees spoke concerning Mr. George Howard Darwin, and Professor Hallock and Professor Cattell concerning Lord Rayleigh. The honorary members were then unanimously elected.

The following list of corresponding members was nominated by the Council, and the Secretary was instructed to cast one ballot for their election, which was done:

Dr. Louis Dollo, Brussels, Belgium.
Dr. Otto Jaekel, Berlin, Germany.
Prof. Dr. Eberhard Fraas, Stuttgart, Germany.
Prof. Dr. Charles Depéret, Lyons, France.
Dr. C. W. Andrews, London, England.
Dr. Max Schlosser, Munich, Germany.
Mr. G. H. Boulenger, London, England.
Prof. G. B. Howes, London, England.
Dr. Walter Innes, Cairo, Egypt.
Dr. A. Liversidge, Sydney, New South Wales, Australia.
Prof. Mansfield Merriman, South Bethlehem, Pa., U. S. A.
Dr. Stuart Weller, Chicago, Ill., U. S. A.
Prof. Ludwig Boltzmann, Vienna, Austria.
Dr. A. Smith Woodward, London, England.
Prof. Dr. Fried. Kohlrausch, Berlin, Germany.
Prof. R. H. Traquair, Edinburgh, Scotland.
Prof. W. C. Brögger, Christiania, Norway.
Mr. J. G. Baker, Kew, England.
Prof. Wilhelm Ostwald, Leipzig, Germany.

The following list of resident members was nominated as Fellows by the Council, and were all unanimously elected :

Prof. J. McK. Cattell,
Dr. F. M. Chapman,
Dr. T. M. Cheesman,
Prof. D. W. Hering,
Mr. W. T. Hornaday,
Prof. H. M. Howe,
Prof. F. E. Lloyd,
Dr. L. McI. Luquer,
Dr. Morris Loeb,
Prof. L. M. Underwood,
Dr. J. A. Blake,
Dr. G. N. Calkins,
Prof. G. S. Huntington,
Prof. F. S. Lee,
Prof. T. M. Prudden,
Mr. G. van Ingen,
Dr. J. L. Wortman.

The President then appointed as tellers Professor Lee, Dr. Wortman and Mr. Crampton, ballots were distributed, votes received and counted, and the following officers for the succeeding year were declared elected :

President—Henry F. Osborn.
First Vice-President—James F. Kemp.
Second Vice-President—Charles L. Bristol.
Corresponding Secretary—William Stratford.
Recording Secretary—Richard E. Dodge.
Treasurer—Charles F. Cox.
Librarian—Bashford Dean.
Councilors—Franz Boas, William Hallock, Charles A. Doremus, Harold Jacoby, Lawrence A. McLouth, L. M. Underwood.
Curators—Harrison G. Dyar, Alexis A. Julien, George F. Kunz, Louis H. Laudy, William D. Schoonmaker.
Finance Committee—Henry Dudley, John H. Hinton, Cornelius Van Brunt.

At the close of the business part of the meeting Professor **H. F. Osborn** delivered the Presidential address entitled THE MAMMALIAN SUCCESSION IN AMERICA AS COMPARED WITH THAT IN EUROPE IN TERTIARY TIMES.

After adjournment an informal reception was held.

RICHARD E. DODGE,
Recording Secretary.

ANNUAL REPORT OF THE RECORDING SECRETARY.

The last year of the Academy has been a very satisfactory one in many ways. The interest in our meetings and in our work has continually increased, and is perhaps greater at the present time than for many years. The membership has increased extensively, and the affairs of the Academy are in a very pleasing condition.

During the year from March 1, 1898, there have been seven meetings of the Council, fourteen business meetings of the Academy, thirty-one meetings of the several sections, three public lectures, and one public reception. The Sections of Astronomy and Physics, of Biology, and of Geology and Mineralogy have met each month, except that the Section of Biology lost a meeting in February, owing to the severe storm. The Section of Astronomy and Physics had an additional meeting in June. The Section of Anthropology, Psychology and Philology has been divided into sub-sections, for the purposes of economy of effort, and the sub-section of Anthropology and Psychology has held four meetings, the sub-section of Philology two meetings. Particular mention should be made of the good work and increased interest in the sub-section of Anthropology and Psychology, largely due to the personal and persistent efforts of Dr. Boas.

During the year a total of ninety-four papers has been presented before the Academy, including those of three public lectures. They may be classified as follows, viz.,

Anatomy 3.
Anthropology 8.
Archæology 2.
Astronomy 3.
Botany 1.
Chemistry 1.
Comparative Geology 1.
Descriptive Geology 7.
Economic Geology 7.
Mechanics 5.
Mineralogy 1.
Palæontology 5.
Petrography 4.
Philology 10.
Physics 10.
Physiology 2.
Psychology 7.
Sociology 17.

Thirty-seven members have been elected, twelve have resigned, one has been dropped for non-payment of dues, leaving a total of 350 on the secretary's list, a difference of twenty over last year. The nominations of two honorary members, twenty corresponding members, and seventeen fellows are now pending.

The Fifth Annual Reception, held in April last, was in some ways the most successful in the history of the Academy, and was certainly more scientific and pleasing. A very large number of guests attended during the two evenings and one afternoon of the reception, and seemed extremely interested in the results there exhibited. A number of changes in certain important particulars have been made during the last year. The by-laws have been very completely revised and simplified, and made workable, particularly in such a way as to give the individual sections and sectional officers more importance in the program, and in reducing the number of business meetings at which the Academy must be organized by the president and secretary to one a month.

The public lectures have been established on a better footing than heretofore, and have been announced as to date a year in advance, and assigned to the various sections, so that each of the different departments of science may be popularly represented. During the summer the program of the meetings of the year, containing also certain information for ready reference, was issued. This program has been found very helpful and will probably be continued.

The publications of the Academy have been greatly improved as to quality, appearance and dignity, by the change incorporated in January last, when the TRANSACTIONS were abolished. The thanks of the Academy are certainly due to our enthusiastic and very careful Editor, Mr. van Ingen, for the great amount of work and care that he has put upon the publications. It is through the publications only that we are known abroad in the world, and it is very necessary that we should thus appear in the most favorable manner possible.

The Academy is in great need of more money for publication, and our efforts should be devoted as fully as possible to the securing of contributions for such work. We are continually obliged to decline valuable scientific papers by our members because of lack of funds for printing. This is a condition of affairs which should not be allowed to continue long. It is a great pleasure to the Academy to feel that certain of the scientific wants of the city are soon to be met, owing to the encouragement given by one of our Patrons who has always been interested in the Academy. I refer particularly to the gift to the Scientific Alliance, of which the New York Academy of Sciences is the original member, of $10,000 for a scientific building, given by Mrs. Herrman. During the coming year it is hoped to bring the several sections in touch so as to have a uniform policy of procedure and the manner of printing the proceedings will be simplified and unified. No special plans of procedure are under discussion.

RICHARD E. DODGE,
Recording Secretary.

ANNUAL REPORT OF THE TREASURER.

For the Year Ending February 27, 1899.

RECEIPTS.

Balance on hand as per last Annual Report		$737.40
Income, Permanent Fund	$420.14	
" Publication Fund	90.00	
" Audubon Fund	89.86	600.00
Life Membership Fees		600.00
Initiation Fees		170.00
Annual Dues, 1896	$ 40.00	
" 1897	135.00	
" 1898	2,155.00	
" 1899	70.00	2,400.00
		$4,507.40

DISBURSEMENTS.

Cost of publishing ANNALS	$2,105.02	
Less amount contributed by Mr. R. Stuyvesant	476.71	$1,628.31
Cost of publishing TRANSACTIONS		11.86

Expenses of Recording Secretary......		$336.47
" Corresponding Secretary...		11.36
" Treasurer...............		39.71
" Librarian		45.00
Rent of Rooms	253.00	
Janitorial Services.......	3.00	
Insurance Premium..................	5.00	
Expenses of Lectures...............	19.75	
General Expenses..................	17.25	
Expenses of Fifth Annual Reception ...	580.82	
Dues to the Scientific Alliance.........	66.02	3,017.55
Balance, Cash now on hand...........		$1,489.85

Details of Permanent Fund.

Balance as per last Annual Report...............	$698.68
Life Membership Fees received during the year....	600.00
Initiation Fees received during the year...........	170.00
Balance now on hand....................	$1,468.68

Details of Audubon Fund.

Balance as per last Annual Report	$212.86
Accumulation of Income during year............	89.86
Balance now on hand....................	$302.72

Details of General Income Account.

Deficiency as per last Annual Report		$174.14
Cost of Publishing ANNALS and TRANSACTIONS.....		1,640.17
Expenses of Officers..........................		432.54
Rent of Rooms...............................		253.00
Expenses of Fifth Annual Reception.............		580.82
Other Expenses.............................		111.02
		$3,191.69
Income from Permanent Fund.........	$420.14	
" Publication Fund.........	90.00	
Annual Dues	2,400.00	$2,910.14
Deficiency, due Permanent Fund.		$281.55

Summary.

Balance to credit of Permanent Fund	$1,468.68
" " Audubon Fund	302.72
	$1,771.40
Less Deficit in General Income account	281.55
Balance, cash on hand	$1,489.85

Assets.

Cash in Bank		$1,489.85
Investments in Bonds and Mortgages:		
a/c Permanent Fund	$8,402.75	
a/c Publication Fund	1,800.00	
a/c Audubon Fund	1,797.25	12,000.00
Annual Dues in Arrears:		
For 1895	10.00	
" 1896	50.00	
" 1897	190.00	
" 1898	370.00	620.00
Total		$14,109.85
As against amount last year		$13,207.40

Respectfully submitted,
C. F. Cox,
Treasurer.

Above report has been compared with the Treasurer's books and vouchers and found correct.

John H. Hinton,
For the Finance Committee.

ANNUAL REPORT OF THE LIBRARIAN.

February 27, 1899.

Since the last Annual Report of the Librarian, the library has been removed from the old library building of Columbia University, and is now shelved in Schermerhorn Hall, in accordance with the terms of agreement between the Academy and the University.

Dr. Bashford Dean has been especially active, as a member of the Library Committee, in supervising the arrangement of the books and in determining the sequence to be adopted.

The present room is ample for the accommodation of the books at date, and space remains for a considerable amount of expansion.

Everything relating to the library has necessarily been in a more or less chaotic condition during the process of removal, but from now on the books will be available for reference.

All the accessions during the year have been stored in the gallery of the Museum of Fossil Plants and Vertebrates, in Schermerhorn Hall. In the same gallery are also all the back numbers of the Academy's publications. The former should be incorporated in the library as soon as possible, in order that we may be in a position to know what numbers of any serials are lacking. The latter should be carefully sorted and a certain number of each issue should be filed where they can be readily obtained for filling requests for back numbers, subscriptions, etc., and the remainder stored, either in packages or boxes, labelled and arranged in sequence. In order that all this may be accomplished, considerable assistance will be required, which the incoming librarian will be in a better position to recommend than I can at the present time.

Mr. van Ingen reports concerning requests for back numbers that a large number of requests have been received during the last two years, but until quite recently it has been impossible to fill the orders because of the great confusion resulting from the obligatory stacking of the back number in piles on the floor of the gallery of room 104, Schermerhorn Hall. Lately some order has been put into the mass, and all the requests will soon have been attended to.

Accompanying this report are several communications received by me as librarian and also accounts with vouchers, showing expenditures on behalf of the library. A balance of $7.33 is in my hands, which is subject to the instructions of the Academy.

I would suggest that I be authorized to place it where it can be available for the payment of expressage, postage due on returned mail matter, and other incidentals.

Respectfully submitted,
ARTHUR HOLLICK,
Librarian.

BUSINESS MEETING.

MARCH 6, 1899.

Academy met at 8 P. M., Vice-President Kemp, presiding.

The minutes of the last business meeting were read and approved.

The following candidate for resident membership, approved by the Council, was duly elected.

Gustav Langmann, 121 West 57th St.

The name of one candidate for resident membership was read and referred to Council according to the by-laws.

There being no further business, the Academy adjourned.

RICHARD E. DODGE,
Recording Secretary.

SECTION OF ASTRONOMY AND PHYSICS.

MARCH 6, 1899.

Section met at 8 P. M., Mr. P. H. Dudley presiding.

The minutes of the last meeting of section were read and approved.

The following program was offered:

J. K. Rees, THE GREAT HORIZONTAL TELESCOPE FOR THE PARIS EXPOSITION IN 1900.

P. H. Dudley, STRESSES IN RAILS DUE TO THERMAL CHANGES.

The chairman called for nominations of officers to serve for the ensuing year. Professor J. K. Rees, after a few introductory remarks, nominated Professor M. I. Pupin for Chairman and Dr. W. S. Day for Secretary. The candidates were unanimously elected.

SUMMARY OF PAPERS.

The paper by Professor **Rees** was illustrated by lantern views, among which were several of the Yerkes Observatory in Wisconsin, showing not only the great telescope itself, but also the very large dome required in which to mount it. The author then pointed out the problem that the French astronomers had set before them, viz, to construct a telescope that should far surpass the great Yerkes instrument. In order to avoid attempting the construction of a dome for a telescope having a focal length of 200 feet, which would be out of the question, they are building their telescope in a fixed horizontal position, directing the light into it by means of a mirror that may be so moved as to follow the course of a star and so called a siderostat. Professor Rees showed views of the details of the mirror, its mechanism and the methods of polishing it. The object glass of the telescope will be about 49 inches in diameter, and when the instrument is completed, it will be the largest in the world.

Mr. **Dudley** in his paper showed that most of the heavy modern rails are held so tightly by the bolts through the splices, that when great falls of temperature occur, they may break, through an excessive tensil strain, before they can "render" in the splices. On a rise of temperature, strains of compression are set up, so that nearly all breakages occur on a drop in temperature.

R. GORDON,
Secretary.

SECTION OF BIOLOGY.

MARCH 13, 1899.

Section met at 8 P. M., Professor Lee, presiding.

The minutes of the last meeting of the Section were read and approved.

The following program was then offered:

F. B. Summer, OBSERVATIONS ON THE GERM LAYERS OF TELEOST FISHES.

H. L. Clark, FURTHER NOTES ON THE ECHINODERMS OF BERMUDA. Paper presented by Professor C. L. Bristol.

Jonathan Dwight, Jr., THE SEQUENCES OF MOULTS AND PLUMAGES OF THE PASSERINE BIRDS OF NEW YORK STATE.

The Chair appointed Professors H. F. Osborn and C. L. Bristol and Mr. C. F. Cox a committee to consider and nominate candidates for the grant of the John S. Newberry Research Fund.

SUMMARY OF PAPERS.

Mr. **Summer** showed that Teleost eggs can be divided into two types according to their approach to the holoblastic forms of cleavage; that germ disc and yolk cannot strictly be contrasted as epiblast and hypoblast respectively; that the germ-ring arises either by involution or delamination or both; that the "Prostoma" of Kupffer is a reality, his contention that the prostomia represents the entire blastopore being, however, wrong; that the hypoblast in the stone-cat-fish is derived partly from the posterior lip of the prostoma and partly from the germ-ring, perhaps wholly from the prostoma in the trout; that the function of Kupffer's vesicle, which arises as a cleft between the prostomal entoderm and the involuted margin of the blastoderm, is probably the absorption of fluid nutriment elaborated from the yolk by the periblast.

Dr. **Clark's** paper summed up the work on the Echinoderms collected by the New York University Expedition in the summer of '97 and '98, and presented a check list of the Echinoderms thus far reported from Bermuda. The collection of 1898 was especially rich in holothurians, containing many species hitherto collected, adding several others to the list from Bermuda, and one new to science. From his work on *Stichopus*, Dr. Clark suggested that the different forms found in Bermuda may be mature and immature individuals of *S. möbii* (Semp.). *Synapta vivipora* was found under conditions widely different from those in Jamaica. The new *Synapta* is allied to *S. inhaerens* and Dr. Clark has named it *S. acanthia*.

The Echinoderms from Bermuda are distributed as follows: Asteroidae 4; Ophiuroidea 7; Echinoidae 8; Holothuroidae 10.

Dr. **Dwight** fully described the process of moult in its relation to the plumage of about one hundred and fifty species of land birds common to eastern North America. The early plumage of these birds was described together with the time and method of the acquisition of later plumages. Stress was laid upon the underlying principles of the sequence or succession of plumages peculiar to each species, and the moults and plumages were classified according to a definite scheme by the author.

GARY N. CALKINS,
Secretary.

SECTION OF GEOLOGY AND MINERALOGY.

MARCH 20, 1899.

Section met at 8 P. M., Professor Kemp, presiding.

The minutes of the last meeting of Section were read and approved.

The following program was then offered:

Richard E. Dodge, A LAKE HISTORY IN NORTHERN NEW YORK, illustrated by diagrams.

John D. Irving, THE GEOLOGY OF THE NORTHERN BLACK HILLS AND THEIR SILICEOUS GOLD ORES, with illustrations by lantern and by specimens.

Mr. G. F. Kunz was nominated and elected as Chairman, and Dr. Alexis A. Julien as Secretary of Section for ensuing year.

The subject of Mr. Irving's paper was further discussed by Mr. **John H. Caswell** and by the Chairman.

ALEXIS A. JULIEN,
Secretary.

SUB-SECTION OF ANTHROPOLOGY AND PSYCHOLOGY.

MARCH 27, 1899.

The annual meeting of the Sub-section was called to order by the Secretary of the Academy, Professor R. E. Dodge. The following officers were elected for the ensuing year: Chairman, Dr. Franz Boas; Secretary, Dr. C. H. Judd.

The following program was then presented :

Livingston Farrand, NOTES OF CHILCOTIN MYTHOLOGY.

M. H. Saville, ZAPOTECAN ANTIQUITIES.

A. Hrdlicka, ZAPOTECAN SKULLS.

Charles B. Bliss, RECENT SUGGESTIONS FOR A NEW PSYCHOLOGY.

SUMMARY OF PAPERS.

In Dr. **Farrand's** paper several typical myths of the Chilcotin tribe were described and attention was called to similarities in details between these and the traditions of neighboring tribes of British Columbia. The bearing of these facts on the question of transmission or independent origin of myths was discussed and it was argued that while independent origin must be admitted as a general principle, transmission must also be invoked to explain certain similarities. The fact of transmission can be shown not only on the inherent evidence of the traditions themselves but also on historical evidences of the borrowing and adoption of myths from other tribes within the memory of individuals still living.

The next two papers described and discussed the results of the recent expeditions to excavate among the Zapotecan ruins.

The third paper was a review of René Worms' "Psychologie collective et psychologie individuelle," a paper recently read by Worms before L'Academie des Sciences Morales et Politiques.

CHARLES H. JUDD,
Secretary.

SUB-SECTION OF PHILOLOGY.

MONDAY, MARCH 27, 1899.

Sub-section met at 8:30 P. M., Professor A. V. Williams Jackson, presiding.

The minutes of the last meeting of Section were read and approved. The names of two candidates for resident membership were read and referred to the Council according to the By-Laws.

Mr. **Jackson** called attention to the coming address to be delivered before the Sub-section, on April 28, by Professor **C. R. Lanman,** on THE NEW SCHOLAR : HIS AIMS AND HIS PROBLEMS.

The following program was offered:

E. H. Babbitt, College Words and Phrases.

Louis H. Gray, Contributions to Avestan Syntax, the Conditional Sentence.

A. V. Williams Jackson, Notes on the Drama of Ancient India.

Summary of Papers.

Mr. **Babbitt** first drew attention to the plan which had been carried into effect by the American Dialect Society to collect data with reference to collegiate vocabulary and students' slang. He explained that more than one hundred replies had been received from various colleges and these replies, written on blanks prepared for the purpose, gave a good idea of the words and phrases employed by students in different parts of America in their academic relations, their sports and associations and in their daily college life. Mr. Babbitt gave results from 700 or more titles and he drew attention to the Dialectic Society's forthcoming publication which would make current the material gathered.

In the discussion which followed, Professor **Kemp** and Professor **Sihler**—the latter an invited guest—commented on the lists by making some additions and by comparing with German university student phrases.

Mr. **Gray,** Fellow in Indo-Iranian languages at Columbia University, in the second communication of the evening, presented some new and important syntactical results from the Avesta. From an extensive study of the conditional sentence of the Avesta, Mr. Gray was able for the first time clearly to prove the exact points of resemblance between the Protasis and Apodosis in Avestan as compared with the Sanskrit and the Greek. He pointed out in detail in what respect the Avestan conditional sentence was older than the Greek.

Professor **Jackson** presented some of the results of his studies in the Sanskrit Drama with reference to the observance or non-observance of the unity of time. He confined his discussion to the three extant plays of Kālidāsa. He first showed by a detailed analysis that the action of the Drama Malavika is comprised in six days; the romantic plays Śakuntala and Urvaśi, on the other hand, cover a period of several years in their action. The examination included an interpretation of several passages.

In the miscellaneous business Professor Sihler called attention to the coming meeting of the American Philological Association which is to be held at New York University in July. This will be the first meeting of the association held in New York since 1876.

The question of the election of officers for the sub-section was postponed. The sub-section then adjourned.

A. V. Williams Jackson,
Secretary.

PUBLIC LECTURE.

March 31, 1899.

An illustrated lecture under the auspices of the Section of Biology, by Professor **Henry F. Osborn**, and entitled, Recent Discoveries Among the Dinosaurs, drew a good-sized and interested audience. Professor Osborn illustrated his description by lantern slides and sections. At the close of the lecture a vote of thanks was extended to the lecturer.

Francis E. Lloyd,
Secretary.

BUSINESS MEETING.

April 3, 1899.

Academy met at 8 P. M., President Osborn, presiding.

The minutes of the last business meeting were read and approved.

The Secretary reported from the Council as follows: That the edition of the Annals, beginning with the first part of the volume for 1899 will be increased from 1000 to 1250 copies.

The following candidates for resident membership, approved by the Council, were duly elected:

Woodbury G. Langdon, 719 Fifth Ave.
James P. Hall, Tribune Building.
James McNaughton, 1 Broadway.
L. J. R. Holst, 52 East Union Square.
William Dutcher, 525 Manhattan Ave.

The name of one candidate for resident membership was read and referred to Council according to the By-laws.

The following paper was read by title, and referred to the Publication Committee, viz.,

Theodore G. White, THE BLACK RIVER, TRENTON AND UTICA FORMATIONS IN THE CHAMPLAIN VALLEY OF NEW YORK AND VERMONT.

President **Osborn** then spoke at some length concerning the work of the late Professor O. C. Marsh, of Yale University. President Osborn spoke of the fact that the great trio of American vertebrate palæontologists, Leidy, Cope and Marsh, had now passed away. He then considered in detail the results that Professor Marsh had given to the world in the last twenty years concerning vertebrate palæontology, and spoke particularly of the importance of his discoveries concerning the ancestry of the horse, and also concerning the great group of dinosaurs.

At the close of this brief but forceful eulogy, the Academy adjourned.

RICHARD E. DODGE,
Recording Secretary.

SECTION OF BIOLOGY.

APRIL 3, 1899.

Section met at 8 P. M., Professor F. S. Lee presiding.

The minutes of the last meeting of Section were read and approved.

The following program was then offered :

R. Ellsworth Call, THE ZOOLOGY OF MAMMOTH CAVE.

N. R. Harrington, THE SENFF ZOOLOGICAL EXPEDITION.

SUMMARY OF PAPERS.

Dr. **Call** records in this paper the number and classification of the fauna of Mammoth Cave, Kentucky. It includes remarks on the distribution within the cave and on the habits of the several forms. These habits were not dissimilar to those exhibited by related groups not epigeal and were believed to be indicative of out-of-door origin. Thus, the habit of hiding under sticks and stones in a region of perpetual darkness, from enemies who like themselves were devoid of eyes, or if possessing them, were so aborted that they were useless, was cited as an indication that the earlier ancestors of the present cave species were out-door species which became adopted to their changed environment but had not lost the habits acquired by their ancestor above ground.

The various forms of spiders, the coleoptera, the orthoptera, all exhibit habits quite similar to those of species which live above ground.

The so-called "cave rat," popularly believed to be blind, is in fact not so. Experiments on specimens kept in captivity for some time seem to indicate that the power of vision was only lessened, but not destroyed, by the change in environment.

The nest-building habits of the cave *Neotoma* were given at some length and it was remarked that much of materials left by earlier explorers was utilized by these animals for nest-building materials. With this habit was correlated the supposed antiquity of certain piles of canes, partly burnt, left by the aboriginal visitors to the cave and commonly believed to be of very great age from the fact that they were found under large rocks "which must have fallen after" the piles were formed. This conclusion was rendered invalid by the observation that many of these piles contained the fragments of cane with burnt ends arranged in every possible manner and were evidently simply carried thither by these animals in building nests among the loose rocks. Tobacco plant buds, acorns, hickory nuts, and similar miscellaneous matters testify to the recency of these piles in opposition to the theory of great age.

The colors of certain of the coleoptera, chestnut brown or mahogany, were cited as an indication of rather recent origin, the forms not having lived long enough under ground to have lost all color. It was shown that loss of coloration in pigmentation was a slow process and had not yet been completed with these forms.

Lantern slides and drawings illustrated the paper.

Mr. **Harrington** described the work of the expedition which was directed to the lower Nile. The campaign of the English against Khartum made it impossible to visit the upper Nile. Short descriptions of a number of the fish of the region visited, and of the method of fishing used by the natives were illustrated, together with the work of the party, by specimens and lantern slides.

A communication from Dr. Bashford Dean was read recommending Mr. Francis B. Sumner as the recipient of the grant of the Newberry Research Fund for 1899. This recommendation had previously been approved by the sectional committee on nominations.

FRANCIS E. LLOYD,
Secretary.

SECTION OF ASTRONOMY AND PHYSICS.

APRIL 10, 1899.

Section met at 8.15 P. M., Professor M. I. Pupin presiding.

The minutes of the last meeting of Section were read and approved.

The following program was then offered:

Cope Whitehouse, SOLAR RADIATION.

A. S. Chessin, ON THE TEMPERATURE OF GASEOUS CELESTIAL BODIES.

W. C. Kretz, ON THE POSITIONS AND PROPER MOTIONS OF STARS IN COMA BERENICES, from Rutherfurd Photographs.

SUMMARY OF PAPERS.

In the second paper, Dr. **Chessin** showed that Dr. See's so-called law, $RT =$ a constant, was not a law at all, and was the result of erroneous calculations. He also called attention to the calculations of A. Ritter on the same subject, in "Wiedemann's

Annalen" for 1878. He showed how far from applicable to the actual facts most of these theoretical discussions and calculations are.

In the discussion Professor Pupin called attention to the fact that in the concentration of a heavenly body the work done by gravitation might be an excessively small fraction of the total work done by all the forces, including particularly the forces of chemical affinity. But we cannot at present base any calculations on these as we know so little about them.

Professor Rees said that if astronomers cannot yet solve these problems, it is because they cannot get the proper knowledge from the physicists on the physical parts of the question.

In the third paper, Mr. **W. C. Kretz** related that Rutherfurd took fourteen photographs in the years 1870, 1875, and 1876, of the cluster in Coma Berenices. The positions of these stars on the plates were measured with a Repsold measuring machine, and the reduction was made by the method worked out by Professor Jacoby. Great precautions were taken to eliminate all possible errors. The positions obtained were compared with those obtained by Chase with the Yale heliometer in 1892. In this manner a catalogue of the positions and proper motions of 24 stars was obtained, which was the object of the research.

In the discussion, Professor Rees said that the Academy should be proud of Mr. Rutherfurd. He also expressed appreciation of the generosity of Miss Bruce, who has altogether given something over $22,000 for carrying out several important pieces of work.

On motion of Professor Rees, it was voted that the paper be referred to the publication committee of the Council.

The section then adjourned.

WM. S. DAY,
Secretary.

SECTION OF GEOLOGY AND MINERALOGY.

APRIL 17, 1899.

Section met at 8:15 P. M., Professor J. J. Stevenson presiding.

The minutes of the last meeting of Section were read and approved.

The following program was then offered :

A. A. Julien, NOTE ON A FELDSPAR FROM THE CALUMET COPPER MINE, KEWEENAW POINT, MICH.

E. O. Hovey, GEOLOGICAL AND MINERALOGICAL NOTES GATHERED DURING A COLLECTING TRIP IN RUSSIA.

SUMMARY OF PAPERS.

The feldspar from the Calumet Mine is of common occurrence in museum-collections and was originally taken by some mineralogists as a form of leonhardite, but has since been generally recognized as orthoclase, although this has not been confirmed by any analysis on record.

Occurrence.—The specimens described below were gathered from the outcrop of the vein at the Calumet Mine, a few days after its first opening. The feldspar was here abundantly distributed through the cellular brownish material of the amygdaloidal melaphyre. It lined the sides of the cavities in crusts up to 1 cm. in thickness, and even completely filled them, thus making red aggregates 5 or 6 cm. in length, united by irregular branching seams in an almost continuous network. The interiors of these geodes were often completely filled with white calcite, rarely showing minute strings of metallic copper. Elsewhere the calcite had been partially or entirely removed, showing the drusy surface of orthoclase, here and there studded with green spots and films of malachite and chrysocolla, scales of a white talc-like mineral and of brilliant black hematite and dull films of pyrolusite.

Bright red rhombs of apparently the same feldspar also occur at the Calumet Mine in the coarse copper-conglomerate, in two associations : 1st. They lie enclosed within the brown jasper-like pebbles of quartz-porphyry and felsite-porphyry. These rhombs may vary up to 1 cm. or more in length, and their outlines are often more or less rounded, like those of the associated grains of gray quartz. They have been described by R. Pumpelly (Geol. Survey Mich., I. (1873), Pt. II., p. 37), who also states, "It not rarely happens that in these flesh-red crystals there appear dirty green portions exhibiting the twin-striation of a triclinic variety. The feldspar is hard and brilliant, but is nevertheless no longer intact; under the glass the crystals appear cavernous, 10 per cent. or more of the substance being gone." 2d. They are distributed through the interstices between the pebbles in still greater abundance, from 2 to 3 crystals appearing on a square centimeter of surface, with contrast brought out by their bright cleavage-faces on fracture. These crystals commonly enclose minute films and granules of gray quartz, and sometimes particles of gray to white calcite, but never any metallic copper.

At the Portage Lake Mines in the cavities of the conglomerate, the same bright red feldspar is commonly interspersed, often with shining cleavage-faces on the fracture, but sometimes finely granular or dull and then approaching laumontite or other red zeolite in appearance. They often vary from 5 to 10 mm. in length and sometimes reach over 2 cm.

Albany and Boston Mine. The red feldspar-rhombs vary in dimensions from 1 to 4 cm., within the interstices between the pebbles. Epidote is a common associate with analcite, phrenite, quartz, chlorite, calcite and metallic copper.

Huron Mine. The feldspar occurs as in the preceding in association with analcite, laumontite, epidote, calcite, quartz and metallic copper.

Osceola Mine. The feldspar occurs in very minute granules, less than 0.5 mm. across, but occasionally in larger grains, 4 to 9 mm. in length. The same red rhombs also occur in the cavities of the amygdaloid which overlies the conglomerate.

Allouez Mine. Bright red shining rhombs of feldspar, up to two or three mm. across, in the cavities of the conglomerate, associated with calcite, chalcotrichite, malachite and quartz.

Peninsula Mine. The coarse conglomerate contains the same red feldspar in rather inconspicuous grains, mixed with calcite and metallic copper. Occasional pebbles occur, up to 1.5 cm. in length, chiefly made up of the same feldspar in aggregates of shining grains, 1 to 1.5 mm. across, mixed with granules of gray quartz.

Rhode Island Mine. The sides of the cavities in the coarse conglomerate are encrusted with similar salmon-colored to red grains and crystals, usually less than 0.5 mm. across, but varying up to 3 mm. Coarse pebbles also occur here, up to 3 cm. across, which seem to be made up of the same feldspar in dull red grains.

Schoolcraft Mine. The amygdules in the trap (brown amygdaloid) are lined by copper, forming the outer shell; inner layer, red feldspar with interior filling of calcite or delessite.

Orthoclase crystals have also been noted in the conglomerate or amygdaloid, by H. Bauerman, R. Pumpelly and others, at the Phenix, Bohemian, Amygdaloid, Bay State, St. Mary's, Southside, Evergreen Bluff, Michigan, Sheldon and Columbian, Ossipee, and other mines of this district.

In the Ontonagon region, the cavities of the coarse conglomerate contain scattered crystals of the same red feldspar, 2 to 3 mm. across. Many pebbles of quartz-porphyry also occur, whose small phenocrysts seem to consist of the same form of orthoclase.

All the observations point to a wide distribution of this variety of the mineral throughout the copper-bearing rocks of the Lake Superior region, in the cavities of the conglomerate and of the cellular traps.

Form.—The crystals are invariably of a simple type, in most cases rhombic prisms. In the drusy cavities of the amygdaloid at the Calumet Mine, to which the following description applies, the crystals display a single modification, an orthodome on the opposite obtuse angles. Skeleton forms are also common, made up of thin plates, sometimes bent, parallel, or arranged in empty box-like outlines, following rhombic contours; these are plainly results of under-development from lack of material. But elsewhere, in the cavities of the amygdaloid, some feldspar surfaces present a corroded or eaten-out appearance, with dulled lustre, perhaps affected by the same solvent which has carried away the calcite from the core of these geodes.

Many faces and cleavage-planes also exhibit distinct curvature which in some cases is due to many successive offsets of laminæ with sudden projections of portions of the faces. Striations sometimes occur on the faces of some crystals, not like those of a plagioclase, but rather like insets of the feldspar along cleavage-lines of the calcite-filling of the geode. The curvatures, slight distortions and striations look like effects of intense pressure at the contact-surfaces of feldspar and calcite.

Physical Characters.—Lustre almost vitreous. Color, deep orange to brick-red. Hardness about 6.

Specific gravity, 2.455, in distilled water at 21° C. This is extraordinarily low for the mineral, to which only one previous determination corresponds, that of a reddish orthoclase from Marienberg, Saxony, the gangue of tinstone, for which Kröner found the specific gravity to be 2.44.

The mineral is opaque, and, in thin section under the microscope, this is found to be due to the general diffusion of cloudy matter, either white (kaolinic) or bright orange (iron-oxide), with scattered black opaque granules. Translucent spots occur only at rare intervals, and all the indications point to incipient alteration, with little or no removal of material.

Many minute irregular clefts and fissures also traverse the mineral, occupied by films of iron-oxide, and seem to indicate a slight disintegration or shattering of the material, perhaps by expansion; this also may have a bearing on the origin of the curvature above described.

Chemical Composition.—The material for the analysis was carefully picked out to eliminate granules with adhering calcite, in preference to treatment with dilute acid. The latent porosity of the mineral and partial solubility of its amorphous coloring material were shown by the bleaching produced on the edges of fragments, after digestion in acids. The material was dried at 100° C.

The cobalt-oxide was verified by test of residue before the blowpipe. This and the manganese-oxide may have been both derived in part from a chlorite-mineral whose decomposition has produced both the talc-like scales and black stains (pyrolusite) within the geodes. The water, expelled only on ignition, may have been retained in combination with decomposition-products, and a part of the lime with undetermined carbonic acid.

		Molecular Ratio.	Quantitative Ratio.
SiO_2	61.61	1.025	4.100
Al_2O_3	10.87	.106	
Fe_2O_3	5.89	.037	.858
FeO	.73	.010	
CoO	.18	.002	
MgO	.27	.007	
K_2O	14.43	.153	
Na_2O	3.02	.048	.44
MnO	.85	.010	
H_2O	.74	.041	
CaO	1.15	.020	
	99.74		

In interpreting the formula of Orthoclase from these results, with reference to the normal ratio of the quantivalences,

$$R : R : Si = 1 : 3 : 12$$

it seems necessary to assume an isomorphous substitution of a part of the heptads by the dyads, here found in unusual excess.

It also seems natural to connect this excess of protoxides with the general incipient decomposition of the mineral, the minute fractures throughout its material, possibly produced by expansion through absorption of oxygen and water, its remarkably low specific gravity, and perhaps the frequent curvature of its faces and cleavage-planes.

Professor **J. F. Kemp** called attention to the unusual presence of cobalt-oxide in a feldspar, shown in the analysis.

Doctor **Hovey** then gave a very interesting description, with lantern illustrations, of the geological and mineralogical excursions in Russia, held in connection with the recent International Congress. Many of the lantern pictures were beautifully colored; they referred in part to ethnographic observations; and the accompanying remarks awakened much interest.

ALEXIS A. JULIEN,
Secretary.

SIXTH ANNUAL RECEPTION AND EXHIBITION.

The Sixth Annual Reception and Exhibition was held April 19th and 20th at the American Museum. The affair was under the charge of Professor Wm. Hallock, of Columbia University, and was an unqualified success. The number of entries was more limited than customary, and the exhibit thus showed more clearly the progress of science during the year. The exhibition remained open for two evenings and one afternoon and as usual the first evening was devoted to a reception to the members of the Scientific Alliance, and the second evening to a reception to the interested public.

A full account of the reception appears in *Science*, for April 28, 1899.

Richard E. Dodge,
Recording Secretary.

SUB-SECTION OF ANTHROPOLOGY AND PSYCHOLOGY.

April 24, 1899.

Section met at 8 P. M., Dr. Franz Boas presiding.

The following program was then offered:

E. A. Gerrard, An Objective Method of Studying Emotional Expression.

S. I. Franz, On After-Images.

J. R. Swanton, The Structure of the Chinook Language.

Stansbury Hagar, The Astronomical Cosmogony of the Peruvians.

Summary of Papers.

Mr. **Gerrard's** paper presented methods for the study of emotional expression as found in literary compositions. The relative emotional values of the different parts of speech, of different sentence lengths, and other variations in the kind of language used and in its arrangement, were discussed and illustrated by curves derived from a number of writings.

Mr. **Franz** presented some results of experimental investigations of visual after-images. The latent period increases as the area of stimulation decreases ; but it decreases as the intensity or the duration of stimulation increases. The duration of the after-image increases with any increase in the intensity, duration, and area of the stimulation. The after-image of the colors in the middle of the spectrum is not more intense than that of the extreme colors if the intensity of the colors is first equalized. The degree of attention is of the first importance in determining the duration of the after-image. Retinal transference is not real ; its apparent reality is due to the impossibility of distinguishing the fields of vision of the two eyes.

Mr. **Swanton.** Discourse in the Chinook language shows great lack of subordination, its short sentences following each other without connectives. The verbs are aggregations of many pronouns added to a short stem. They serve in this way to epitomize the whole sentence, object and indirect object, as well as subject.

Mr. **Hagar.** The Peruvians, contrary to the generally accepted opinion, were in possession of a large amount of astronomical knowledge. It can be shown that they had a full zodiac, and that their whole political as well as their religious life was controlled by their astronomy. There are also many striking similarities between their terminology and rites and those of other, frequently very remote, peoples.

CHARLES H. JUDD,
Secretary.

PUBLIC LECTURE.

UNDER THE AUSPICES OF THE SUB-SECTION OF PHILOSOPHY.

APRIL 28, 1899.

Professor **Charles R. Lanman,** of Harvard University, delivered a lecture on THE NEW SCHOLAR, HIS IDEAS AND PROBLEMS.

The lecture was a very interesting and thoughtful summary of the modern scholar's ambitions and difficulties, and was followed with pleasure by a good sized audience.

A. V. Williams Jackson,
Secretary.

BUSINESS MEETING.

May 1, 1899.

Academy met at 8:15 P. M., President Osborn presiding.

The minutes of the last meeting were read and approved.

The Secretary reported from the Council as follows: That it had been voted to print a program for next year as had been done for the year just ending. It was also voted that meetings begin next year at 8:15 P. M. sharp. It was also voted to have the Librarian prepare for publication in Annals a catalogue of serials in Library.

The following Candidates for resident membership, approved by the Council, were duly elected.

Dr. J. Alder, 12 East 60th Street.

Professor Edward F. Buchner, 3 West 63d Street.

The Secretary announced that Professor Kemp had been made a life member, in accordance with the regulations of the By-Laws.

William S. Day,
Secretary pro tem.

SECTION OF ASTRONOMY AND PHYSICS.

May 1, 1899.

Section met at 8:25 P. M., Professor M. I. Pupin, presiding. The minutes of the last meeting of Section were read and approved.

The following program was then offered:

M. I. Pupin and **S. G. F. Townsend,** Magnetization of Iron with Alternating Currents, Preliminary Account.

C. C. Trowbridge, Phosphorescent Substances at Liquid Air Temperatures.

Summary of Papers.

M. I. Pupin and **S. G. F. Townsend.** The current wave in a transformer with open secondary circuit is a complex harmonic vibration, and the object of the research is to determine the amplitudes and phase relations of the components of the fundamental vibration.

The component due to eddy currents is determined from the curves of electromotive force and current, together with the static hysteresis loop for the given magnetization, by a graphical method. The eddy current component is found to lag behind the electromotive force. Also, the dynamic hysteresis loop is shown to have a rounded point, as distinguished from the sharp point characteristic of the static loop.

The phase of the fundamental of the total current is found by means of a specially constructed phase-meter. Its amplitude is determined from the electromotive force and total watts.

The remaining component to be determined is that due to hysteresis and induction reaction. This and the eddy current component form two sides of a parallelogram of which the fundamental of the total current wave is the diagonal. If the last two are determined in amplitude and phase, the fundamental of the distorted wave of magnetizing current can readily be found.

The ultimate object of the investigation is to formulate the laws which govern the reactions accompanying the magnetization of iron by alternating currents.

C. C. Trowbridge. Calcium sulphide, made phosphorescent by exposure to sunlight at ordinary temperatures, was made non-luminous by immersion in liquid air. Then when allowed to heat up gradually to normal temperature, the phosphorescence again became visible at about —100° to —75° C. The same material, if exposed to sunlight while immersed in liquid air, phosphoresced faintly while still immersed. When exposed to the electric arc it phosphoresced strongly. In both of these cases the phosphorescence became brighter when the temperature was raised. From these results and what was previously known, it was concluded that when a phosphorescent substance, like calcium sulphide, is excited by light, the phosphorescent energy will be given up at the temperature of excitation, even when as low as —190° C., but if it is cooled below the temperature of excitation, the phosphorescent discharge is arrested, and remains so until the temperature is raised again until it is within at least 100° of the temperature of excitation.

It was found that calcium tungstate which gives a whitish fluorescence when exposed to Roentgen rays, gave a green phosphorescence when exposed to light while immersed in liquid air.

Wm. S. Day.
Secretary.

SECTION OF BIOLOGY.

May 8, 1899.

Section met at 8:10 P.M., Professor F. S. Lee, presiding. The minutes of the last meeting of Section were read and approved.

The following program was then offered:

W. R. Rankin, Notes on the Crustacea of Bermuda, Collected by the New York University Expeditions of 1897 and 1898.

H. F. Osborn, Upon the Structure of the Feet of the Mule-Footed Hog of Texas.

H. F. Osborn, Upon a Complete Skeleton of Tylosaurus Dyspelor, Including the Cartilaginous Sternum.

Summary of Papers.

Professor **Rankin's** paper gives a list of 61 recorded species of crustacea from the Bermuda Islands. The paper appears in full on pages 521–548 of the present volume of the Annals. Of the total number of species, 43 were found by the expedition, and notes on their distribution are given. Eight of these 43 species are new to the Bermudas, and two, *Nika bermudensis* and *Alpheus lancirostris* are new species. The genus *Nika* is for the first time recorded from the West Atlantic region.

The physical conditions of the islands are touched on, and the crustacea are shown to be in the main similar to those found in the West Indies and the adjacent coasts of America; though 18 have a more or less extended range over both hemispheres.

Professor **Osborn** reported upon the anatomy of the feet of a specimen of the well known "mule-footed hog" of Texas, recently presented to the Zoölogical Museum of Columbia by Dr. Wickes Washburn. Externally the feet present the appearance of complete fusion of the third and fourth toes. Internally, however, considerable differences are observed. In the pes, the third and fourth metapodials and the first phalanges are entirely separated and normal, and the second pair of phalanges are closely united and the terminal phalanx is also closely united, so it has the appearance of a single element. The fusion is less advanced in the manus; here the metapodials, first and second phalanges are separate, one of the second phalanges being abnormally hypertrophied and a supernumerary element being inserted beneath it. The terminal phalanges are very firmly united into a single element, which holds the bones above it together.

Discussion followed, during the course of which, Professor **Bristol** stated that a large number of experiments were being carried on at a western ranch to ascertain the effects of breeding upon this peculiar variety. Professor Osborn remarked that this anomaly presented an interesting case of the persistence of a character which must have originated as a sport.

Professor **Osborn's** second paper included a description of the remarkable complete skeleton of a Mosasaur, recently mounted in the American Museum of Natural History. The skeleton was procured in 1897, from the famous Smoky Hill Cretaceous beds of Kansas, through Mr. Bourne and has been worked out with the greatest care. It is practically complete as far back as the 78th caudal, and the bones are approximately in position, including the fore and hind paddle and, what is more remarkable, almost complete cartilaginous sternum, sternal ribs and epicoracoids. The species represents the largest type of American Mosasaur, *Tylosaurus dyspelor* Cope. As illustrated by numerous photographs and drawings, the specimen throws a flood of new light upon the structure of the Mosasaurs. The principal characters are the following: 7 cervicals, 10 dorsals connected with the sternum by cartilaginous ribs, 12 dorsals with floating ribs, 1 sacral and 72 caudals (out of a total number of 86); coracoids connected by broad epicoracoids having a transverse diameter of 22 cm. The sternum is triangular in shape tapering posteriorly and having the general form of that in *Trachydosaurus*. There is no evidence of an episternum, the shoulder girdle in general being more degenerate than *Platacarpus*, in which an episternum has been observed. The fore paddles are smaller than the hind ones and include two coösified carpals. The fifth digit is somewhat enlarged and set well apart from the others. The hind paddle is slightly larger and very completely preserved. The tail is remarkable in presenting an upward curvature in the mid region, which probably supported a prominent caudal fin, but it is not angulated as in *Ichthyosaurus*. The skull shows the presence of epipterygoids. The total length of the skeleton as preserved is a little over 27 feet, the estimated total length of the animal is 30 feet. In mounting a single large panel has been used, the animal lying upon its ventral surface, with the paddles outstretched, the sides of the back bone curved in a graceful manner exactly as originally imbedded in the matrix.

FRANCIS E. LLOYD,
Secretary.

SECTION OF GEOLOGY AND MINERALOGY.

MAY 15, 1899.

Section met at 8:15 P. M., Dr. A. A. Julien presiding. The minutes of the last meeting of Section were read and approved.

The following program was then offered:

Arthur Hollick, A RECONNOISSANCE OF THE ELIZABETH ISLANDS, MASSACHUSETTS.

W. Goold Levison, NOTES ON: (1) PHOTOGRAPHS OF MINERALS FOR ILLUSTRATING BOOKS AND LECTURES.

(2) PHOTOMICROGRAPHS OF OPAQUE MICROSCOPIC MINERALS FOR ILLUSTRATING BOOKS AND LECTURES.

(3) A METHOD OF SHOWING THE ACTION UPON PHOTOGRAPHIC PLATES, OF BECQUEREL RAYS FROM MINERALS, SERVING AS A TEST TO DETECT THE EMISSION OF SUCH RAYS.

Above illustrated by lantern slides.

(4) DETACHABLE FOOT FOR A PORTABLE MICROSCOPE.

(5) PRELIMINARY NOTE ON THE CHEMICAL COMPOSITION AND SOME PHYSICAL PROPERTIES OF A MINERAL FROM THE TOPAZ LOCALITY, HUBBARD MINE, TRUMBULL, CONNECTICUT.

Heinrich Ries, PRELIMINARY NOTES ON THE PHYSICAL PROPERTIES OF CLAYS.

SUMMARY OF PAPERS.

Doctor **Hollick's** paper was illustrated by specimens, photographs, sketches and charts. The Elizabeth Islands extend in a southwesterly direction from Wood's Hole, Mass., forming the barrier between Buzzard's Bay on the north and Vineyard Sound on the south. The principal islands are five in number, and beginning at the eastern end of the group they are known as Naushon, including Nonamessett, Uncatina, Pine Island, Buck Island and the Weepeckets, Pasque, Nashaweena, Penikese (including Gull Island), and Cuttyhunk. Little or nothing has been written in regard to them for the reason that each island, with the exception of Cuttyhunk, on which there are a number of separate holdings, belongs to some one individual, family or corporation; hence there is no line of public travel to or through them and no house of public enter tainment, except in connection with Cuttyhunk. The trip occupied a week and was made possible through the courtesy and kindness of the owners. Taken as a whole the islands represent a partially submerged morainal ridge, which has become separated into islands and isolated from the mainland in recent geological times. They apparently represent a later, more northern branch of the terminal moraine, the southern or older portion of which is represented by Montauk Point, Block Island and Martha's Vineyard. One of the most interesting discoveries was an exposure of plastic and lignitic clay, presumably Cretaceous in age, on the south side of Nonamessett. The proximity of this locality to the mainland leads to the inference that other deposits of the same age, which have escaped erosion, may be found further north, up the old estuaries, where theoretically the formation once extended. The general surface features of the islands are such as are characteristic of typical morainal regions, consisting of rounded hills and corresponding depressions, many of the latter occupied by ponds or swamps.

In the discussion, replying to an inquiry by Professor Kemp, Dr. Hollick stated that only indefinite lignite remains had been detected in the deposits, and that no ilmenite boulders had been recognized. The chairman explained that the *Pinus rigida*, of sparse occurrence on Naushon, was the prevailing conifer along the south shore of Cape Cod to the eastward, while, on the other hand, the beech was rarely found on the Cape. The morainic chain of the Elizabeth Islands extended to the northerly part of the Cape, in Brewster and Orleans, separated from the south shore by modified glacial deposits in Dennis, Harwich and Chatham.

Professor **R. E. Dodge** was inclined to believe that the whole aspect of the topography of these islands was that of a drowned shoreline, modified by subsequent erosive action, probably not caused by easterly winds.

Professor **J. F. Kemp** favored the view of the author, that present erosive action was mainly concerned; and Dr. Hollick pointed out that the prevailing direction of the wind was southeast, that extremely violent currents prevailed in the channels, especially during ebb-tides, that sandspits occurred only at the east end of the channels, and that, during the process of sinking and erosion, the embayments deepened, met and united, and thus the channels were cut through.

Doctor **Levison** exhibited by the lantern six photographs of minerals, natrolite and calcite, taken by reflected light; four enlargements of photomicrographs, by reflected light, of minute groups of aragonite, apophyllite and stilbite; a new method of showing the photographic action of the Becquerel rays on a sensitive plate, by use of a written inscription on a card, in the form of a glue-line dusted with the powdered uraninite ; a simple mode of attachment of a separate foot to a microscope, in order to render it portable ; and read a note on a visit to the Hubbard Mine, Fairfield County, Connecticut, with description and analysis of apparently a new lithia mineral from that locality.

The Chairman suggested that such photographic enlargements might be of great service for study of faces and even goniometric determinations on very minute crystals, where numbers of such crystals were arranged in coincident planes and proper adjustments could be made.

In the absence of Dr. **Ries**, an abstract of his paper was presented by Professor Kemp, with emphasis on two important conclusions : first, that the plasticity of clays was not caused by the predominance of any particular constituent, such as kaolin, but by the physical coherence of minute surfaces ; second, that the fusibility of clays was due, not so much to their mineral components, but to their ultimate chemical composition, and that this could be therefore practically improved, when necessary, by intermixture with the proper constituents.

The Academy then adjourned to October 2, 1899.

ALEXIS A. JULIEN,
Secretary.

BUSINESS MEETING.

OCTOBER 2, 1899.

Academy met at 8 P. M., Professor Osborn, presiding. The minutes of the last business meeting were read and approved.

The Secretary reported from the Council that Doctor Theodore G. White had been made a life member, in accordance with the regulations of the By-Laws.

The president welcomed the members of the Academy to the Session, 1899–1900, and spoke of the promise of a very interesting series of meetings during the winter, covering the reports and papers based upon observations made during the previous summer. In this connection he alluded to the activity of members of the Academy in many widely different fields of research, and to the death of Mr. Nathan R. Harrington, whose plans for an expedition up the Nile had been presented at one of the last meetings of the Academy. Allusion was also made to the loss the Academy had sustained in the death of Judge Charles P. Daly. Two members of the Academy had been recently elected to important offices in the American Association for the Advancement of Science, and it is incumbent upon the Academy to prepare for the meeting of the Association in New York City during the month of June, 1900.

A committee consisting of Professors Kemp, Britton and Stevenson was appointed to draw up suitable resolutions concerning Judge Charles P. Daly.

RICHARD E. DODGE,
Recording Secretary.

SECTION OF ASTRONOMY AND PHYSICS.

OCTOBER 2, 1899.

Section met at 8.40 P. M., Professor M. I. Pupin, presiding. The minutes of the last meeting of the Section were read and approved.

The following program was offered:

William Hallock, COMPOUND HARMONIC VIBRATIONS OF A STRING.

SUMMARY OF PAPER.

Professor **Hallock**. Some German investigators have experimentally determined by photography the motion of a point of a string. The vibration varies of course according to the part of the string bowed, the speed, the kind of bow, etc.

This communication consisted essentially of a set of curves showing successive positions of a string vibrating under the influence of a fundamental, and the first seven overtones, each curve showing the position of the string at a particular instant. Sixteen such curves were shown for the first sixteen sixty-fourths of a complete period of the fundamental. The amplitude of the component was proportional to the wave-lengths, in each case. Thirty-two points were computed for each curve.

Each curve is computed from the formula

$$y_1 = a \sin 2\pi \frac{t_1}{T_1} \sin 2\pi \frac{x_1}{l_1} + b \sin 2\pi \frac{t_1}{T_2} \sin 2\pi \frac{x_1}{l_2} + \text{etc.}$$

$$+ h \sin 2\pi \frac{t_1}{T_8} \sin 2\pi \frac{x_1}{l_8}$$

$$a = 2b = 3c = 4d = 5e = 6f = 7g = 8h$$

$$T_1 = 2T_2 = 3T_3 = 4T_4 = 5T_5 = 6T_6 = 7T_7 = 8T_8.$$

In the discussion, Professor **Pupin** said that it would be interesting to photograph the vibration of a string loaded, and then unloaded. Such a study might help our theories of electrical waves along a cable.

WM. S. DAY,
Secretary.

SECTION OF BIOLOGY.

OCTOBER 9, 1899.

Section met at 8:15 P. M., Professor Frederic S. Lee, presiding. The minutes of the last meeting of Section were read and approved. The names of 4 candidates for resident membership were read and referred to the Council according to the By-Laws.

The evening was devoted to reports of the past summer's work by a number of members.

SUMMARY OF PAPERS.

Professor **H. F. Osborn** gave an account of the EXPLORATION BY THE AMERICAN MUSEUM PARTY IN THE COMO BEDS OF SOUTHERN WYOMING, and of further work in the Bone Cabin Quarry, which resulted in the discovery of a large number of the remains of *Dinosaurs.* Four miles distant a *Brontosaur* skeleton was found. Parties were also sent to the Freeze-out Mountains and north to the Rattlesnake Mountains, but without success.

Professor **E. B. Wilson** reported upon his SEARCH IN EGYPT FOR POLYPTERUS, which resulted in the obtaining of a few fine females, but with unripe ovaries; this was in winter, between Assuan and Mansourah. Professor Wilson reported also the rediscovery by him of the gillbearing earthworm, *Alma.*

Professor **Bashford Dean** reported on the work of the SECOND SENFF EXPEDITION TO THE NILE, and spoke of the death of Nathan Russell Harrington, the senior member of the party. Mr. Harrington had for four years identified himself with the Biological Section, and had left with it an enviable example of energetic and persistent effort to complete an important research and of sacrifice and devotion to a life-work.

Professor **Dean** further reported on his work on the California coast while a guest of Stanford University. He was successful during the present summer in obtaining a number of freshly hatched young of *Bdellostoma*, and many developmental stages of *Chimæra colliei.*

Doctor **G. N. Calkins** reported the passing of a successful summer at the Marine Biological Laboratory at Wood's Hole, where he was at work upon the Protozoa.

Professor **F. E. Lloyd** gave a brief account of a collecting trip in Vermont, embodying some remarks upon certain species of *Lycopodium* found there. He also reported upon the marked success of the Biological Laboratory at Cold Spring Harbor during the summer.

Professor **F. S. Lee** spoke on the continuation of his experimental work upon the lateral line in fishes, conducted at Woods Hole.

FRANCIS E. LLOYD,
Secretary.

SECTION OF GEOLOGY AND MINERALOGY.

OCTOBER 16, 1899.

Section met at 8 P. M., Mr. Geo. F. Kunz, presiding. The minutes of the last meeting of Section were read and approved.

The following program was then offered:

G. F. Kunz, EXHIBITIONS OF VARIOUS MINERALOGICAL SPECIMENS.

J. F. Kemp, ON THE OCCURRENCE OF IDOCRASE AT SEVEN DEVILS, MONTANA.

J. J. Stevenson, THE SECTION AT SCHOHARIE, NEW YORK.

J. F. Kemp, GEOLOGICAL SURVEY OF THE ADIRONDACK REGION.

H. F. Osborn, VISIT TO THE COMO BLUFFS SECTION.

R. E. Dodge, WORK AT PUEBLO BONILO, NEW MEXICO.

A. A. Julien, DISTRIBUTION OF OPAL OR HYALITE.

G. F. Kunz, VISIT TO THE ANCIENT LOCALITY OF JADE AT JORDANSMÜHL NEAR BRESLAU, GERMANY.

E. O. Hovey, EXCURSION TO YELLOWSTONE PARK.

SUMMARY OF PAPERS.

Mr. **Kunz** exhibited the following specimens:

Idocrase crystals in compact erubescite, from vicinity of Boseman, Montana.

Precious opal cementing a fine sandstone, from Alabama.

Struvite from the old locality at Hamburg, Germany, collected about fifty years ago by Mr. Bartha.

Illustrations from the Imperial Printing Works at Vienna, Austria. These were manufactured by the process of covering the surface of the fossil or other natural object with a thin coating of molybdenite; running between rollers: connecting the film with galvanic battery in a bath of metallic salt and printing from electrotype thus produced.

Professor **Kemp** remarked on the occurrence of idocrase, garnet and epidote together with copper ores, at the contact zones of eruptives on limestones, as illustrated by various copper deposits in the Western states, *e. g.*, at Seven Devils in Montana, where epidote and hematite contain bornite, and, in a number of places in Mexico, where epidote, idocrase and garnet have served as characteristic minerals for the identification of such zones.

The regular paper of the evening was then delivered by Professor **Stevenson.** The Schoharie valley is an indentation in the Helderberg mountains, about 35 miles southwest from Albany, New York. It shows a section from the Hudson to the Hamilton groups with almost continuous exposures at various localities. This was examined during the summer of 1899 with the view of making comparisons with conditions observed in parts of the Appalachian region, within Pennsylvania and Virginia.

There are some notable contrasts between the northern and the southern sections. At Schoharie, the Medina is wanting and the greenish shales of Clinton rest on the Hudson. In southern Pennsylvania and in Virginia the red and white Medina are both present and Hudson forms pass upward into the red Medina, occurring abundantly in southwest Virginia in a bed 100 feet below the white Medina. At Schoharie, the Niagara is differentiated physically from the overlying Waterlime, but much of the Niagara fauna passes into the Waterlime; in localities further west and south, the Salina shales intervene and there is no passage of fauna. The upper Waterlime at Schoharie differs greatly in color and composition from the Tentaculite or lower division of the Helderberg, but at least two forms, most characteristic of the Tentaculite, are found in the upper waterlime. These forms were not observed by the writer in the Waterlime of southern Pennsylvania. The several subdivisions of the Helderberg are very distinct physically, the boundaries of each being sharply defined; but the physical changes were such as to cause only gradual disappearance of the several faunas and forms, which persist throughout, showing little variation. The passage from Helderberg to Oriskany at Schoharie is abrupt to the last degree—from a very good limestone to a ferruginous and only slightly calcareous sandstone. The faunal change is as abrupt as the physical. Here again the contrast is very great, for in southern Pennsylvania the passage from Helderberg to Oriskany is very gradual, through a silicious limestone containing forms belonging to each. In southwest Virginia, the upper part of the Helderberg becomes silicious and in some localities is almost a sandstone.

Doctor **Hovey** then referred to some recent observations on evidences of glaciation in a quarry at Schoharie, the surface of the limestone showing a very smooth planing with very minute scratches, though some grooves occur which are quite deep.

Professor **Stevenson** pointed out that the pre-glacial form of the valley was clearly about the same as at present, the action ot the glacier having been entirely ineffective. On some of the projecting limestone beds, the edges have been just rounded off, while the face of the step has entirely escaped glaciation; on others the face also is smoothed and striated. In his view the opportunities for palæontological research were far from being exhausted in the Schoharie Valley, and he referred to the supplies of fossils stored up in certain stone fences, and the dangers to be incurred from indignant farmers.

The Chairman related incidents connected with the arrest of Mr. J. De Morgan at a visit in 1877, for breaking down stone walls, and his rescue by the village tailor.

Professor **Osborn** stated that the results of an excursion to the Schoharie Valley in 1876, in which he participated, led to the formation of the first scientific expedition of Princeton College.

Professor **D. S. Martin** also gave reminiscences of an early visit to this classic locality.

The Chairman called upon the members present to present notes on geological observations during the last summer.

Professor **Kemp** reported on the progress of his geological survey of the Adirondack region. One result was the recognition of a true quartzite of pre-Cambrian date, affording thus a fragmental sediment. The sedimentary rocks in the region he found to be widely charged with graphite, indicating an abundance of organic life in pre-Cambrian time. Further types of eruptive rocks had also been identified to fill up gaps in known series.

Professor **Osborn** related some results of a visit, with Dr. Matthew, to the Como Bluffs Section, south of the Union Pacific R. R., 3 hours west of Laramie; the more certain establishment of its Jurassic character with a bed containing remains of Dinosaurus about 40 feet below the top (a fresh water deposit), while in the marine beds beneath, Belemnites and Betanodon were found, the latter serving as nuclei for large concretions. The search for skeletons was no longer confined to the bluffs, but chiefly directed to the level grass lands below. Quarries have been plotted in detail, during this excursion, for exact location of bones hitherto discovered. On the slopes of the Freeze-out Mountains, fine outcrops of underlying Trias were recognized, in probable substantiation of Professor Marsh's conclusion as to the existence of the Jurassic below.

He also described the mode of occurrence of the mastodon recently found by a German, while digging in his market garden, three miles back of Newburgh, N. Y. The skull was first found and was injured by the excavator; afterward the tusks, backbone, scapula and pelvis, but no limb bones. The association of many stems, gnawed by beavers, indicated the probability of a series of dams, which successively caused a rising of the waters and the deposit of the layers of humus, etc., over these bones.

Professor **Dodge** gave a preliminary account of his work at Pueblo Bonito, New Mexico, during the summer. The object of the work was to find evidence concerning the antiquity of the Pueblo ruins in the Chaco Cañon. The evidence to be obtained from the deposits on which the ruins are situated, seems to indicate a very long occupation of the country previous to the desertion of the ruins.

Doctor **Julien** discussed the common distribution of opal or hyalite; the exclusively recent character of all existing occurrences of this mineral, in seams, veins and contact deposits; its transitional and unstable character and ready passage into more permanent forms of silica; its apparent survival in small proportion in the soluble part of chalcedony and its varieties; the probability that some of the known geological aggregations of amorphous silica (chert, hornstone, etc.) were not deposited as such, but originally in the form of opaline silica; and the office of this diffused mineralizer in the silicification of fossils.

Mr. **Kunz** described his recent visit to the ancient locality of jade (nephrite) at Jordansmühl, near Breslau, Germany, with the special object of study of the minerals associated with jade. In an ancient quarry for road material, immense masses of zoisite-quartzite occurred, forming columns thirty feet in height. In one of these a single mass of pure jade was found, 4,817 pounds in weight, which was separated and has been transported to this country. This is estimated to be five times the bulk of all the jade implements now stored in European museums, and this implies that there is no need to search for an Asiatic origin of their material. A similar deposit of nephrite in place was discovered in 1897 by Professor Jascewski at Cham Folga and Onot in eastern Siberia.

Doctor **Hovey** presented some notes of an excursion with Professor Iddings to the Yellowstone Park, with its novel opportunities of geologizing with a field glass. In the Black Hills the picturesque Pinnacles were described, which have been produced by the resistance of pegmatite-veins to erosion; the red beds, in which a layer of ancient oyster-shells was examined; the Wind Cave, with its stalactites; and the spodumene deposits in abandoned tin drifts, where the spodumene crystals lie like logs, often 30 feet in length and 30 to 40 inches across, commonly mined and shipped to New York for the extraction of lithia, while the accompanying tin ore is thrown aside.

Alexis A. Julien,
Secretary.

SECTION OF ANTHROPOLOGY AND PSYCHOLOGY.

October 23, 1899.

Section met at 8.15 P. M., Dr. F. Boas, presiding. The minutes of the last meeting of Section were read and approved.

The following program was then offered:

E. L. Thorndike, On Mental Fatigue.

Livingston Farrand, Basketry Design of the Salish Indians.

Charles H. Judd, Movement and Consciousness.

Summary of Papers.

Dr. **Thorndike** stated that mental fatigue may mean either the fact of incompetency to do certain mental work or a feeling of incompetency which parallels the fact or the feeling or feelings denoted by our common expressions "mentally tired," "mentally exhausted." Among the conclusions to which the experiments have lead are the following: first, that the fact of incompetency is not what it has been supposed to be; second, that there is no pure feeling of incompetency which parallels it and is its sign, that consequently the mental states ordinarily designated by the phrases mentioned are not states made up of such a feeling of incompetency, but are very complex affairs; and third, that these mental states are in no sense parallels or measures of the decrease in ability to do mental work. The experiments show no decrease in amount, speed or accuracy of work in the evenings of days of hard mental work over mornings or in periods immediately following prolonged mental work over periods preceding it.

Dr. **Farrand's** paper was a contribution to the solution of the problem of the evolution of decorative art, and particularly of the question of development of geometric patterns from realistic portrayals of natural objects. Attention was confined to the basketry designs of the Salish Indians of British Columbia and western Washington, which exhibit certain peculiarities marking them off rather sharply from the designs used by neighboring stocks. It was shown that while the adjacent tribes in the northwest make use almost exclusively of animal designs, and their conventionalism is of a unique nature and not geometric, the tendency of the Salish decorations, on the other hand, is entirely in the direction of extreme geometric conventionalization and the use of animal motives is not predominant. The question of variants and of convergent evolution in designs were discussed and the points made were illustrated by the exhibition of a large number of designs taken from the baskets collected by the Jesup North Pacific Expedition from the region under discussion.

Dr. **Judd's** paper referred to the recent psychological discussions which have emphasized the importance of movement and motor nervous processes as conditions of consciousness. It was pointed out that just as psychology must look for the conditions of sensation elements in non-psychical processes, so a careful analysis of the facts of perception force us to look for the represented factors and for the synthetic activities in non-psychical conditions. In support of this position examples were cited in which the representative factors were not capable of conscious revival even with concentrated attention, and it was shown that synthetic activities become progressively less conscious the more complete and immediate the process of perception becomes. Finally, the attempt was made to discover in the facts of movement and in the nervous processes which follow the reception of sensory stimulations, the conditions of perceptual synthesis and the conditions which make possible the present effects of past experience without complete or even partial revival of any sensory factors, either as revived sensations or as repeated sensory stimulations in the nervous system.

CHARLES H. JUDD,
Secretary.

PUBLIC LECTURE.

OCTOBER 30, 1899.

UNDER THE AUSPICES OF THE SECTION OF ANTHROPOLOGY AND PSYCHOLOGY.

Professor **Hugo Munsterberg** of Harvard University lectured to a large audience on THE PSYCHICAL AND PHYSICAL WORLD.

The Professor pointed out that the science of Psychology must seek to discover the factors of mental phenomena which are more elementary than sensations. These factors are the psychical atoms. Some of their attributes may be inferred from the similarities which exist among sensations and from the fusions which take place between sensations. Such atoms are not forms of reality, but logical concepts made necessary by the demands of explanatory science.

CHARLES H. JUDD,
Secretary.

SECTION OF ASTRONOMY AND PHYSICS.

DECEMBER 4, 1899.

Section met at 8:15 P. M., Professor M. I. Pupin, presiding. The minutes of the last meeting of Section were read and approved.

The following program was then offered:

M. I. Pupin, LONG ELECTRICAL WAVES, WITH EXPERIMENTAL DEMONSTRATIONS.

SUMMARY OF PAPERS.

Professor **Pupin** gave a brief outline of the mathematical theory of the propagation of electrical waves and exhibited apparatus by means of which he had performed experiments bearing upon this theory. He pointed out that the most essential quantities to be considered in wave propagation are the wave length and the attenuation. The wave length plays a more important part in purely scientific investigations, whereas the attenuation constant is of prime importance in electrical engineering. The difficulties met with in long distance telegraphy and telephony are due to attenuation. The lecturer pointed out how both of these quantities could be determined experimentally with an artificial cable, which he exhibited. One of the most important conclusions drawn from these experiments deals with the method of decreasing the attenuation constant by increasing the reactance of the line. The lecturer performed several experiments for the purpose of illustrating the methods which he described in the course of his lecture. The subject has been published in full in the *Transactions of the American Institute of Electrical Engineers*, Vol. 15, p. 111, 1899, to which reference is made.

WM. S. DAY,
Secretary.

SECTION OF GEOLOGY AND MINERALOGY.

December 18, 1899.

Section met at 8:15 P. M., Professor J. J. Stevenson, presiding. The minutes of the last meeting of Section were read and approved.

The following program was then offered:

J. F. Kemp, (1) Recent Theories Regarding the Cause of Glacial Climate.

(2) Metamorphosed Dikes in the Mica Schists of Morningside Heights.

W. D. Matthew, Notes on the Geology of the Laramie Plains and Rattlesnake Mountains in Wyoming.

Summary of Papers.

During the subsequent discussion of the first paper by Professors R. E. Dodge, D. S. Martin and others, Professor **Stevenson** called attention to the fact that the great excess in the area of the peat bogs on the surface of the earth, during the present period, over that of the swamps which prevailed during the Carboniferous, shows the little foundation for the hypothesis of an excess of carbon dioxide in the atmosphere during the formation of coal.

Dr. **Julien** also pointed out, in reference to the theory of the refrigerating influence of the absorption of carbon dioxide from the atmosphere, during the decay of rocks, that this effect may have been more than offset by the heat produced during the accompanying absorption of oxygen.

In the discussion of the second paper, Dr. **Julien** acknowledged the resemblance of outcrop of black hornblende schist to a sheared dike, produced by its strong constrast in color with the enclosing light gray micaceous gneiss; and by the sharp lines of separation of the schist from the highly tilted beds on either side, as if thrust up from below. But this is but one of hundreds of exactly similar outcrops in New York and Westchester Counties. All are intercalated, however, as thin beds in the

Manhattan Series; in not a single case has a hornblende schist been observed to cross the other beds. If one or all of these are dikes, the lamination of the associated beds must also have been effected by a general shearing. But the series is accepted as typically metamorphic, a succession of true beds of altered sandstone (quartzitic gneiss), shales (mica schist), magnesian schists (dolomite marble), etc., into which the injection of trap dikes exclusively between the beds would be entirely improbable. These hornblende schists, moreover, on Morningside Heights, as elsewhere, thin out along the strike like the other lenticular beds; often become partially or entirely biotitic and quartzose; passing gradually into biotitic schists, biotitic and hornblende gneisses, exactly like those of acidic constitution which enclose the above supposed dike. Indeed a basis element rich in lime and magnesia, is distributed throughout the Manhattan Series, and was originally perhaps hornblendic throughout, or, in the absence of silica, concentrated in the numerous dolomite beds. The more purely hornblendic layers correspond in composition, as shown by the interesting analysis in the author's paper, to beds of altered marl; their density has enabled them to resist and escape, in the present surviving layers, the biotitic alteration which has affected the general series.

In the discussion of the third paper Professor **H. F. Osborn** remarked on the uncertainty of the age of dinosaur-beds, whether Jurassic or Lower Cretaceous. All determinations hitherto have been made by collectors, but neglected by the palæontologists, though the section is here continuous from the Mountain Limestone of the Carboniferous up to the base of the Cretaceous. Nor has the correlation yet been made with the corresponding beds of the Wealden, Purbeck, etc., of England and the European continent. The aeolian theory of the author, however, does not appear consistent with the reported observations of remains of fish in these beds.

The chairman, Professor **Stevenson,** stated that no true Limestone fossils have yet been detected in the bed so called in Wyoming, nor the good evidences yet needed of Jurassic life in the Dinosaur-beds, of other vertebrate life, lacustrine remains, etc., of that age, and for confirmation of synchronism of Jurassic life between the continents. As to the heavy oils of Wyoming, they contain but little paraffin and perhaps less than twenty per cent. of kerosene, and are likely to be worthless, except possibly hereafter for use as a coarse fuel.

ALEXIS A. JULIEN,
Secretary.

SECTION OF ASTRONOMY AND PHYSICS.

NOVEMBER, 6, 1899.

Section met at 8:15 P. M., Professor M. I. Pupin, presiding. The minutes of the last meeting of Section were not read. The name of one candidate for resident membership was read and referred to the Council according to the By-Laws.

The following program was then offered :

J. K. Rees, NOVEMBER METEOR SHOWERS (ILLUSTRATED).

SUMMARY OF PAPER.

Among other things the speaker said that one of the theories of the origin of some meteors was that they were at some time ejected from the sun or moon, earth, or other planets, by volcanic explosions, and if from the earth, they traveled in an orbit that intersected that of the earth. The later theories which identify the meteor streams with comets or the remains of comets, seem most satisfactory. Those meteors which reach the earth have a large percentage of nickel in their composition, and show when they are polished a peculiar and characteristic crystalline structure. A great many of these meteors reach the earth on an average each day, as many as ten million or more, it has been estimated. Interplanetary space is full of them. During the meteor showers, this number is greatly increased. At one place on the earth as many as 240,000 were estimated to have been visible during the eight hours progress of the shower of 1833.

Historical records seem to show that showers of meteors have been seen at intervals of thirty-three years in the fall of the year for some time back. In 1799, Humboldt saw one from the Andes Mountains. In 1833 there was another. Professor H. A. Newton, of Yale, after investigating the subject, predicted another in 1866, which came as predicted. Professor Newton, and Professor Adams of England calculated that there was a large bunch or collection of these meteors traveling around the sun with an orbit of about thirty-three and a quarter years. This orbit at one point intersected the orbit of the earth. It was later shown that this orbit was practically identical with that of Tempel's comet of 1866. Three other similar cases of a connection between the meteor showers and comets have been found, and these seem to indicate either that the showers and comets are identical, or that the meteors are parts of a disintegrated comet.

In observing the meteors, the best results are obtained from photographs. Professor Elkin of Yale has a battery of cameras fastened to an equatorial axis, each camera covering a distinct part of the heavens. By means of two such arrangements several miles apart, the exact distance between the two stations being known, it will be possible to get photographs from which can be deduced with accuracy the path of the meteors, the velocity, and the distance from the earth.

The Columbia University Observatory was obliged, on account of the sale of the old observatory site, and the storage of the instruments, to make arrangements for observing the expected shower from other places. Col. P. S. Michie of West Point, placed the observatory there at the service of Professor Rees, and Mr. C. A. Post, of Bayport, offered his time and instruments. A report on the work done during the week November 13–18, will be presented to the Academy.

W. S. Day,
Secretary.

SECTION OF BIOLOGY.

November 13, 1899.

Section met at 8:15 P. M., Professor F. S. Lee, presiding. The minutes of the last meeting of Section were read and approved.

The following program was then offered:

H. F. Osborn, On the Relation of the Centra and Intercentra in the Cervical Vertebræ of Lizards, Mosasaurs and Sphenodon.

Arthur Hollick, The Discovery of a Mastodon's Tooth and Remains of a Boreal Vegetation on Staten Island.

C. L. Bristol, A Report of the New York University Expedition to the Bermuda Islands in the Summer of 1899.

Summary of Papers.

Professor **Osborn** called attention to the confused statements relating to the cervical vertebræ in the Lizards, Mosasaurs and *Sphenodon*, and pointed out that both Gegenbaur and Wiedersheim, the principal German authorities on the comparative anatomy of vertebrates failed to recognize clearly the important part played by intercentra of the neck region. He then, commencing with *Sphenodon*, pointed out that we have a series of intercentra or intervertebral ossicles, extending throughout the whole length of the backbone, but considerably modified by a coalescence with the atlas and axis. In *Platecarpus*, the Cretaceous Mosasaur, on the other hand, the intercentra of the axis and atlas are entirely free and separate, retaining their primitive wedge-shaped form, while the centrum proper or odontoid process is also free from the axis; in the remaining cervicals the intercentra are secondarily shifted forward upon the hypapophyses. *Varanus*, the monitor lizard, exhibits a still greater extension of these hypapophyses with the intercentra placed at their tips. In *Cyclurus*, on the other hand, the intercentra are still in their primitive position between the vertebræ. There is no question, therefore, that true intercentra are very important elements in Lizards and Mosasaurs, and that they are secondarily modified partly by coalescence with the atlas and partly by adhesion to the hypapophyses, this showing a complete change of function.

The leading facts in Doctor **Hollick's** paper are as follows:

In the Moravian Cemetery at New Dorp, Staten Island, immediately in the rear of the Kunhardt Mausoleum, was a swamp, which covered a superficial area of about 3,600 square feet. A small pool of water accumulated towards the center in time of rain and dried out during drought. The margin was a quaking bog of peat and sedges. It occupied a morainal basin, located about 1,200 feet from the southern edge of the moraine and about 120 feet above tidal level.

During the summer of 1899, in the course of certain improvements in the development of the cemetery, the swamp was drained and the bog muck was dug out, so that at the present time the morainal basin is entirely free of water and mud.

The organic remains, animal and vegetable, brought to light during the progress of this work, show that the basin was the site of a Quaternary pond. The surface deposit was of fine peat and a coarse peat, composed of various kinds of swamp vegetation. Below this was a fine organic mud, containing trunks and branches of trees, to a depth of about five or six feet. Below this was a black, sandy silt, distinctly stratified, and containing numerous cones and small twigs of white spruce [*Picea Canadensis* (Mill.) B. S. P.], a tree of northern range, which does not now extend further south than northern New England and the Adirondacks. Below the cones, at a depth of about 23 feet, was found a Mastodon's molar.

The maximum depth of the entire deposit was about 25 feet and bore every indication of having been laid down in still water, in a continuous and unbroken series of layers; and, inasmuch as it was in a morainal basin, it must all have been post-morainal in age.

A considerable amount of charred wood was also found in connection with the cones, presumably indicating the presence of man. The probabilities are that a pond was formed in the morainal depression immediately after the recession of the ice sheet, and that this pond was a receptacle for silt, dust and decaying vegetation ever since, the accumulations finally filling it up and converting it into a swamp with a little pool of casual water in the middle.

Professor **Dean,** referring to Dr. Hollick's paper, spoke of the occurrence of the remains of the mastodon on Manhattan Island.

During the process of excavation for the ship canal across New York Island at about 122d Street there were found extensive peat remains on the side of the Harlem River, together with sunken logs, which suggested the conditions just referred to on Staten Island. During the canal work, a number of specimens were brought to the speaker for examination. The first of these finds was a number of bits of mastodon tusk, which the workmen had hoped might prove of commercial value. The residue of this find, in the form of poorly preserved bones, had been thrown away. There were subsequently brought for examination bones of the following animals: deer, fox, seal, beaver (jaw), and turtle.

Professor **Bristol** reported upon the third New York University Expedition to Bermuda which left New York on May 27th, via the Quebec Steamship Company's steamer "Orinoco." The last members to return arrived on August 1st. The party consisted of Professor C. L. Bristol, Messrs. F. W. Carpenter, C. E. Brush, Jr., F. Erdwurm, of the graduating class; Messrs. Hill, Magnus and Wooley of the present Junior class, and Mr. A. Benton Muller.

The reconnoissance work of the two former years was continued from White's Island in Hamilton Harbor as headquarters. The buildings on the islands afforded far better facilities for laboratory work than was obtained on the other trips, and also brought the party nearer to the south shore and the Great Sound. An important feature was a series of pools constructed above tide level and supplied with plenty of running sea-water, in which a day's "catch" could be examined alive at leisure. A naphtha launch and a small yacht gave the necessary facilities for collecting. The principal work was reconnoissance and many new forms were found among the Crustacea, Echinoderms, Cœlenterates, Tunicates and Mollusca. Perhaps the most important single trip was that made to North Rock, an isolated fragment of the old atoll-shaped reef, about nine miles out at sea. At dead low tide a small area is laid bare but almost awash, and attainable only in the smoothest of water. Here the life of the ocean swarms and offers rare opportunities for study. As in the former years a large number of the showy fishes that abound in the coral reefs were brought home alive for the New York Aquarium. Notwithstanding the sudden fall of temperature at the northern edge of the Gulf Stream the system of regulation of the temperature was so perfect that less than one per cent. died on the voyage. A pair of green parrot fishes of large size, and a large green murray about eight feet long were the most conspicuous among them, and were living and in good health at the date of the meeting.

FRANCIS E. LLOYD,
Secretary.

SECTION OF GEOLOGY AND MINERALOGY

NOVEMBER 20, 1899.

Section met at 8:15 P. M., Mr. Geo. F. Kunz, presiding. The minutes of the last meeting of Section were read and approved.

On motion by Professor Stevenson, a committee of three was appointed to prepare resolutions in reference to the recent death of its distinguished honorary member, Sir William Dawson, of Montreal.

The following paper was then presented:

Charles Barnard, SOME RECENT CHANGES IN SHORELINE OF NANTUCKET.

SUMMARY OF PAPER.

These changes have become apparent by comparison with the outlines indicated in Shaler's map of 1888 (Bull. No. 53, U. S. Geol. Survey). The shoreline, there represented as nearly straight, from a point just beyond the Range Lights to Brant Point, in the harbor, has become materially changed by a rapid advance of the beach on each side, so that the original shore end of the break-water is lost to sight in the sand or covered by buildings.

On the north shore, beyond the apron beach, the sea has steadily advanced upon the land, the increase of material at the break-water having been evidently derived in large part from the bluffs.

At the eastern end of the harbor the narrow beach, styled the Haulover, between the main island at Manumet and the shore end of Great Point, was broken through by the sea in the storm during the night of December 16, 1896, and the opening has become an inlet a mile in width, with a depth of eleven feet at low water, each end of the remaining beach having been bent back into the harbor in the form of a curved hook. The entrance of the tide through this inlet has caused a decided increase in the five narrow bars of sand, which extend like finger points from the shore of Coatue Beach. It does not appear to have seriously affected the current at the break-water, nor reduced the scouring action of the tides at that point ; but shoals seem to be growing at about one-third the distance between the harbor and the port entrance, at the slackwater caused by meeting of the tides from east and west.

The eastern shore, from the harbor south, shows a rapid destruction by the sea, and at Squam Pond a river of beach sand has been swept in.

At Sankaty Light the apron beach has very considerably increased, particularly at Siasconset, and to the south and west, the width of the beach now reaching about the third of a mile.

A similar advance of the sea is shown along the south shore, though to a less degree than on the east, the wastage of both shores having contributed to build out the apron beach at Siasconset.

The subject was further discussed by Professors R. E. Dodge, J. J. Stevenson, H. L. Osborn, J. F. Kemp and others.

Several specimens of Laurentian limestone, magnetite and corundum from the vicinity of the Palmer Rapids of the Madawaska River, Ontario, Canada, were exhibited.

ALEXIS A. JULIEN,
Secretary.

SECTION OF ANTHROPOLOGY AND PSYCHOLOGY.

November 27, 1899.

Section met at 8:15 P. M., Dr. Franz Boas, presiding.

The following program was then offered:

Dr. **A. Hrdlicka,** Observations on the Navahoes, Physical and Physiological.

Dr. **M. H. Saville,** Notes on the Mexican Codex Telleriano-Remensis.

Dr. **Franz Boas,** The Eskimo of Hudson Bay.

Summary of Papers.

Dr. **Hrdlicka** described the physical characteristics of the Navahoe indians and details of a number of measurements made on fifty adult males and thirty adult females. Observations on the life and social and industrial habits of the tribe were also presented. The language belongs to the Athapascan group. From the physical examinations it appears that the tribe, notwithstanding some evident mixture, is radically allied to the ancient Pueblos and to the short-headed people of to-day in other parts of New Mexico and Arizona, and possibly in old Mexico.

Dr. **Boas'** paper was based on observations made by Captain George Comer of East Haddam, Conn. The paper described particularly the natives of Southampton Island, who heretofore have never been visited. The arts of the tribe show a peculiar development, owing to the lack of materials with which other Eskimo tribes are well supplied. The traditions of the tribes of the west coast of Hudson Bay show remarkable analogies to the traditions of the Athapascan tribes of the McKenzie region. The well-known tradition of the magic flight was among those recorded by Captain Comer. There are traditions which make it evident that the Eskimos of this region believed in the transmigration of souls. The dress of the women is very remarkable, and it was suggested that the enormous pockets in their stockings may be a survival of the custom of carrying the children in the boots, as is still done by the Eskimo of Pond's Bay.

Charles H. Judd.
Secretary.

BUSINESS MEETING.

DECEMBER 4, 1899.

Academy met at 8:15 P. M., Professor Stevenson, presiding. The minutes of the last business meeting were read and approved.

The Secretary reported from the Council that Professor J. F. Kemp would have charge of the Annual Reception in the spring of 1900.

The following Candidates for resident membership, approved by the Council, were duly elected:

Maurice A. Bigelow, Teachers College.
Edward W. Barry, Passaic, N. J.
Walter Bryan, M.D., 215 St., James Place, Brooklyn.
Dr. W. Golden Mortimer, 504 West 146th Street.
Romyn Hitchcock, Hotel Lincoln, Broadway and 57th Street.
H. R. Linville, Boys' High School.
Edward L. Thorndike, Teachers College.
R. S. Woodworth, N. Y. University Medical College.
Dr. Annie D'Zou, 63 Stuyvesant Avenue, Brooklyn.

RICHARD E. DODGE,
Recording Secretary.

SECTION OF BIOLOGY.

DECEMBER 11, 1899.

Section met at 8:15 P. M., Professor Bashford Dean presiding in the absence of Professor F. S. Lee. The minutes of the last meeting of Section were read and approved. The names of two candidates for resident membership were read and referred to the Council according to the By-Laws.

The following program was then offered:

Bashford Dean, CONTRIBUTION TO THE DEVONIAN FISH FAUNA OF OHIO.

H. R. Linville, AN ACCOUNT OF ZOÖLOGICAL EXPLORATIONS ON PUGET SOUND DURING SUMMER OF 1899.

M. A. Howe, VEGETATIVE REPRODUCTION BY MEANS OF BROOD ORGANS IN THE HEPATICÆ.

SUMMARY OF PAPERS.

Professor **Dean** referred to the purchase of the Jay Terrell collection of fishes, by Mr. William E. Dodge, and his presentation of the same to the American Museum. Dr. Dean spoke of the great interest of this material, and described two new forms of Placoderms now in the paleontological museum of Columbia University. The new forms resemble, in the character of their "jaws," the long known *Callognathus*. In one favorably preserved "jaw" the rounded and tooth-bearing margin suggests the condition in *Diplognathus*. In one specimen the shoulder armoring is particularly narrow antero-posteriorly. Several dermal plates are present which are unknown in the anatomy of *Coccosteus*, and their definite position has not been determined. The so-called "pectoral spines," described by Newberry, and referred to by other writers, are now to be regarded as belonging in the region of the mouth. A specimen of one of those in the Terrell collection, presents a well-marked tooth on its margin. In a newly acquired specimen a portion of the body investiture is preserved, which exhibits a smooth surface, from which arise conical eminences in somewhat definite rows, resembling those of *Anchenaspis* (*Thyestes*). Dr. Dean referred also to the mode of occurrence of the Placoderm-bearing concretions in the Cleveland shales. In the region near Linville, Ohio, on the testimony of the veteran collector, Rev. Dr. William Kepler, of Clyde, Ohio, the following arrangement maintains. At the base of the shale are found the smaller species of *Dinichthys* (*D. gouldi*, and *D. intermedius ?*). Above this is a layer of flag stone ten feet in thickness. Overlying this occurs a narrow seam in which are sharks, *Titanichthys* and *Mylostoma*. After an intervening seam, two feet in thickness, a wide band of the shale contains *Dinichthys* and *Trachosteus*. At the top of this shale, after another intervening (sandstone ?) seam, in a layer of 20 to 30 feet thickness, which yields sharks, occur large specimens of *Dinichthys*, and the forms referred to in the present communication.

Doctor **Linville** then reported on his trip to Puget Sound. The party consisted of five members: Dr. H. R. Linville of the Boys' High School, New York City; Professor M. A. Barber of the University of Kansas; Professor E. Morrison of Pacific College, Oregon, and Dr. Linville's father and brother. The work of collecting was not divided among the members of the party, except that Professor Barber gave his entire time to the examination of the flora, while the other working members of the party studied the fauna without reference to particular groups. The methods of collecting employed were "towing," shore collecting, pile collecting and dredging. The towing was attended with no great success, the shore collecting was very profitable, but the greatest interest was in the pile collecting and the dredging. The material collected from all sources abundantly represented every large group except the Protozoa and the Chordates. The collection has not yet been studied systematically.

Enormous quantities of *Noctilucca* have been reported to be present in Scow Bay, a long, narrow inlet two miles from the town, but at the time the bay was explored by the party, *Noctilucca* were not seen. Large red and yellow sponges and a form resembling *Grantia* represented the Sponges.

The Cœlenterates were found in great abundance. There were many representatives of a form resembling *Obelia* and another form resembling *Tubularia.* Medusas allied to *Zygodactyla* occurred in great numbers about the docks. *Thalmantias* also was abundant and so were many unidentified forms. The Scyphomedusæ were represented by *Cyanea.* The Anemones were represented by at least five species, the largest of these being a white *Metridium*, specimens of which frequently exceeded 12 inches in length. This species studded the piles to the depth of 20 feet below low tide mark. Another, a large orange-colored *Metridium*, was dredged in ten fathoms of water in Scow Bay. In the same situation were found small bluish-green forms with slender elongate tentacles. A large mottled, red and green anemone, with large bag-like tentacles was obtained; the latter, however, were also to be found on the piles. Most numerous were the small sand-anemones found attached to the rubble-stone along the beach. Equally important, and as magnificent in size were the Echinoderms. The Asteroids, *Cribrella*, the large 20–24-rayed forms and other species were easily obtained from the piles. Most notable of the Echinoderms, was a species of *Echinus* and *Sphærechinus*, the latter in countless numbers. Of the several species of Holothurians obtained, the most remarkable is the giant *Holothuria californica*. *Herneteaus* of unfamiliar species occur abundantly. *Balanoglossus* had been found there in former years. Annelids were abundant in the sand and a large sessile annelid, with a strong leathery tube, was found attached to the piles. Their luxuriant brown tentacles alternating with the white anemones, form in the green water a wonderful picture.

Among the mollusca the most remarkable in point of size is the large *Cryptochiton stelleri* mentioned in the report of the Columbia University Expedition of 1896. In variation the limpets of Puget Sound are indeed marvellous. Gradations were found from the smooth brown limpet found on the piles, to a rougher, grayish form on the granite boulders, on to the corrugated white ones, found among the barnacles, which also grew upon the boulders. In the latter situation, the ridges on the limpets began at the top of the shell and extended radially to the periphery, closely resembling the barnacles themselves in external markings and in color.

The Crustacea of the Sound are not especially remarkable. Under the bark of the piles, giant and small isopods were found abundantly. The small ones are credited by Mr. Henry F. Moore, of the U. S. Fish Commission with eating the piles through at a point between low and high water marks.

Puget Sound is especially rich in Ascidians, and there are said to be twenty-five species there. One species of simple tunicate as yet undescribed attains the length of nearly five inches.

Dr. **Howe** gave an account of the various means by which the ganectophyte in the Hepaticae reproduces itself without the intervention of the asexual phase. Allusion was made to the formation of the easily detached proliferous branches in *Metz-*

geria, and an outline was given of the developmental history of the gemmae in *Riccardia*, *Marchantia*, *Lunularia*, *Blasia*, *Scapania*, *Radula* and *Cololejeunea*. These gemmae seem in most cases to be modifications of trichomes, and they bear more or less structural resemblance to the protonemata which result from the germination of the spores.

FRANCIS E. LLOYD,
Secretary.

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